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Watanabe et al.

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(54) **METHOD AND APPARATUS FOR POLISHING A SUBSTRATE**

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(73) Assignee: **Asahi Glass Company, Limited**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/512,208**

(22) Filed: **Aug. 30, 2006**

(65) **Prior Publication Data**

US 2007/0000874 A1 Jan. 4, 2007

Related U.S. Application Data

(60) Division of application No. 11/045,089, filed on Jan. 31, 2005, now Pat. No. 7,115,022, which is a continuation of application No. PCT/JP03/09745, filed on Jul. 31, 2003.

(30) **Foreign Application Priority Data**

Jul. 31, 2002 (JP) 2002-223001

(51) **Int. Cl.**
B24B 49/00 (2006.01)

(52) **U.S. Cl.** **451/41**; 451/57; 451/278

(58) **Field of Classification Search** 451/41, 451/57, 260, 267, 278, 289
See application file for complete search history.

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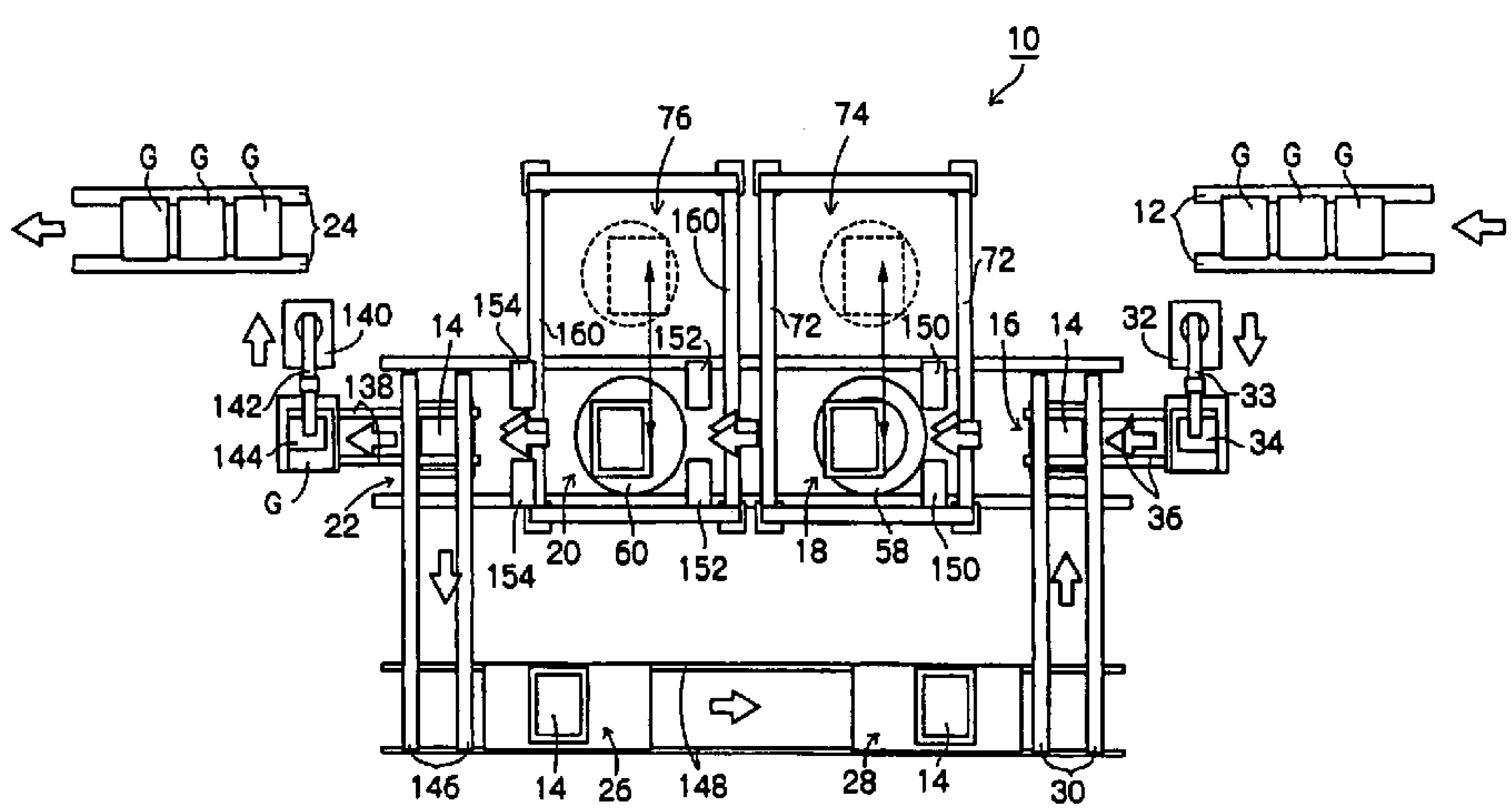
(74) *Attorney, Agent, or Firm*—Oblon, Spivak, McClelland, Maier & Neustadt, P.C.

(57) **ABSTRACT**

The present invention is to provide a method and device for polishing a glass substrate, suitable for polishing a large-sized glass substrate.

The device for polishing a substrate is adapted so that a substrate is attached to a film stretched on a frame; the frame is installed on a carrier; the carrier and a polishing surface-plate are brought closer relative to each other to polish a surface to be polished of the substrate attached to the film by pressing the substrate to the polishing surface-plate; the frame is removed from the carrier after the completion of the polishing, and the polished substrate is removed from the frame.

5 Claims, 37 Drawing Sheets



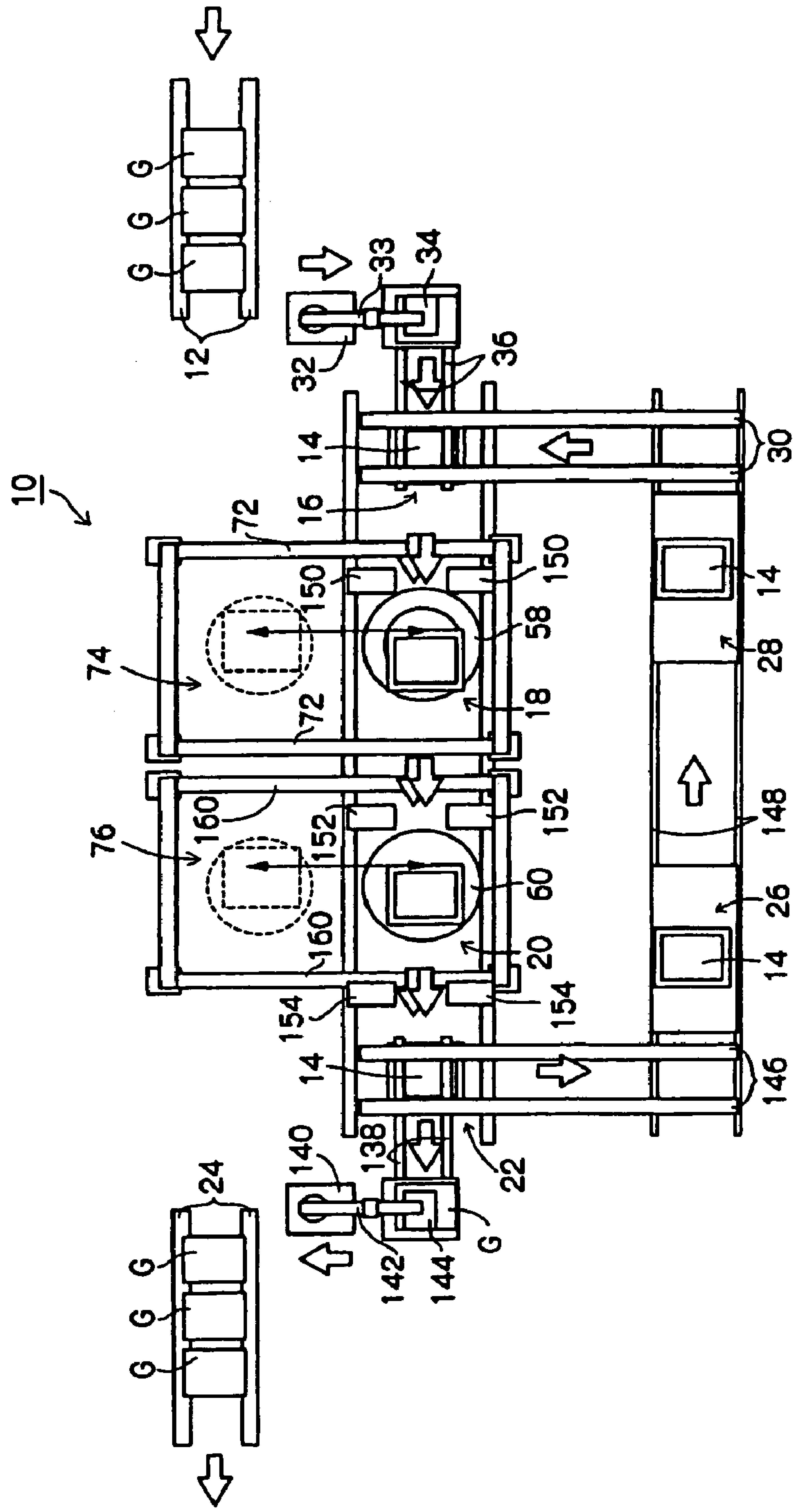

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Fig. 1

Fig. 2

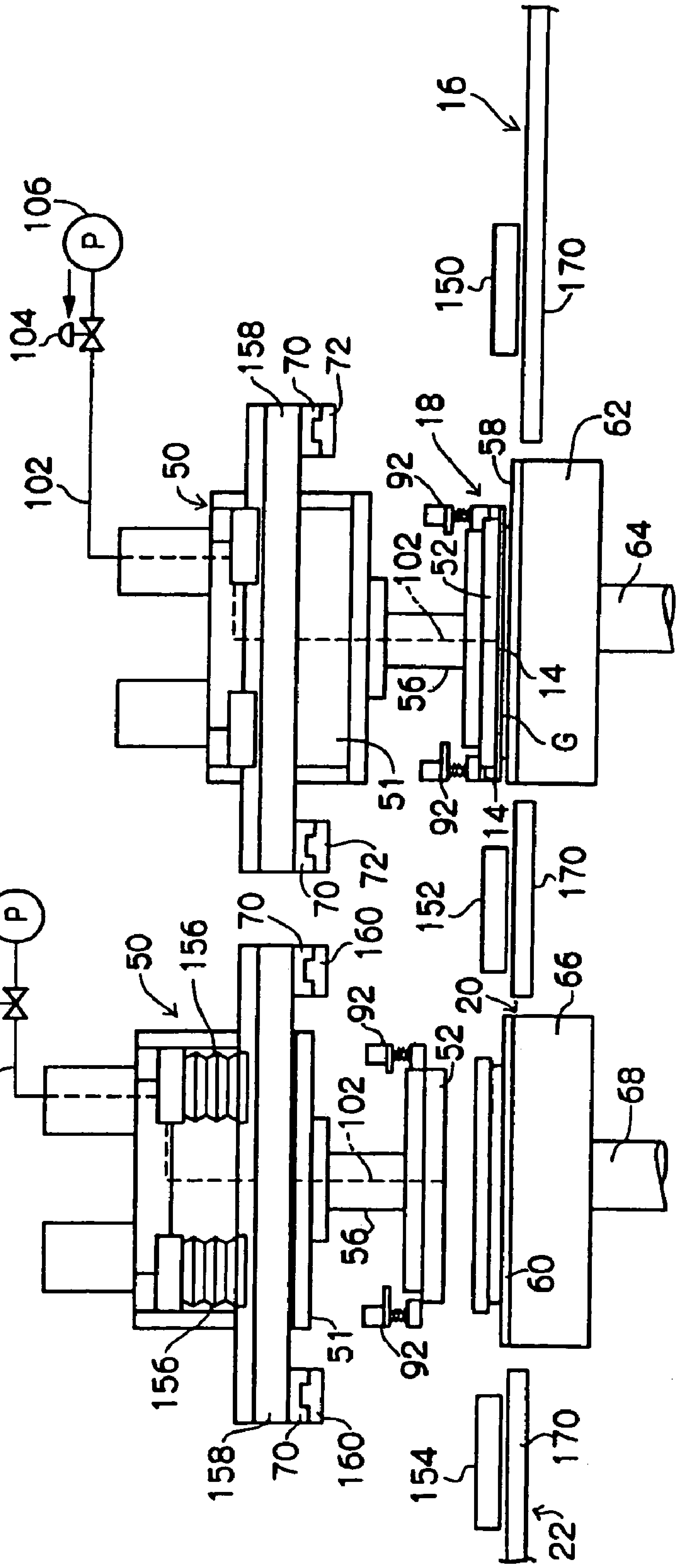
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Fig. 3

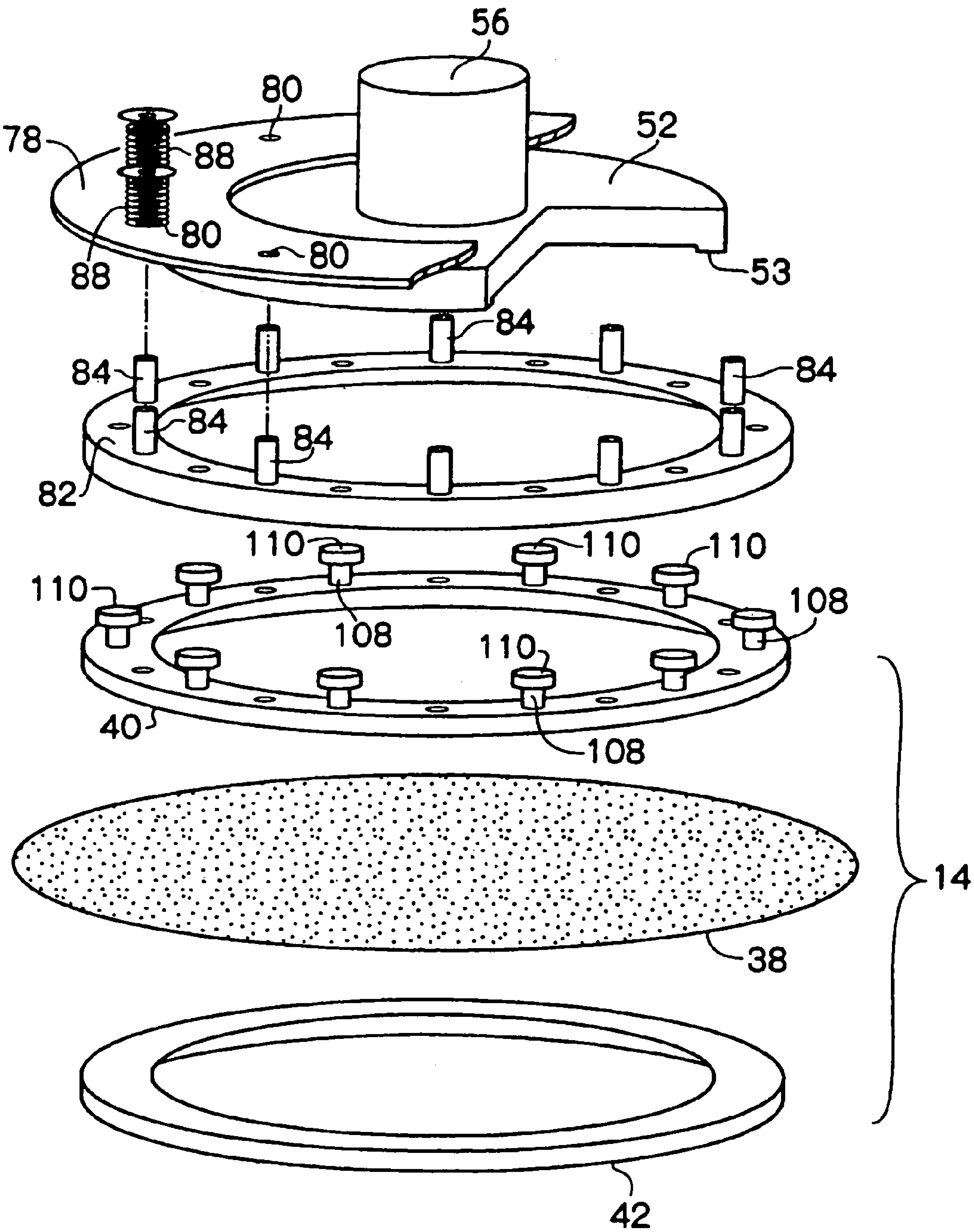
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Fig. 4

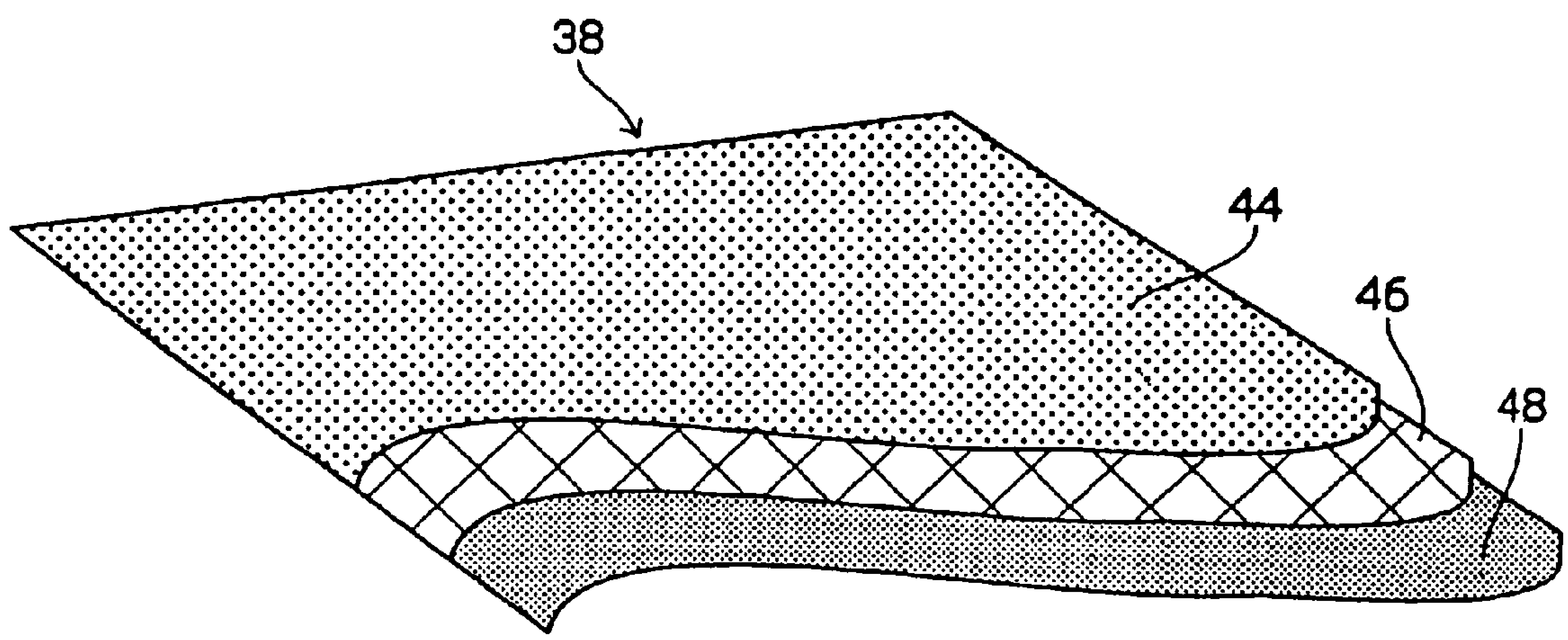
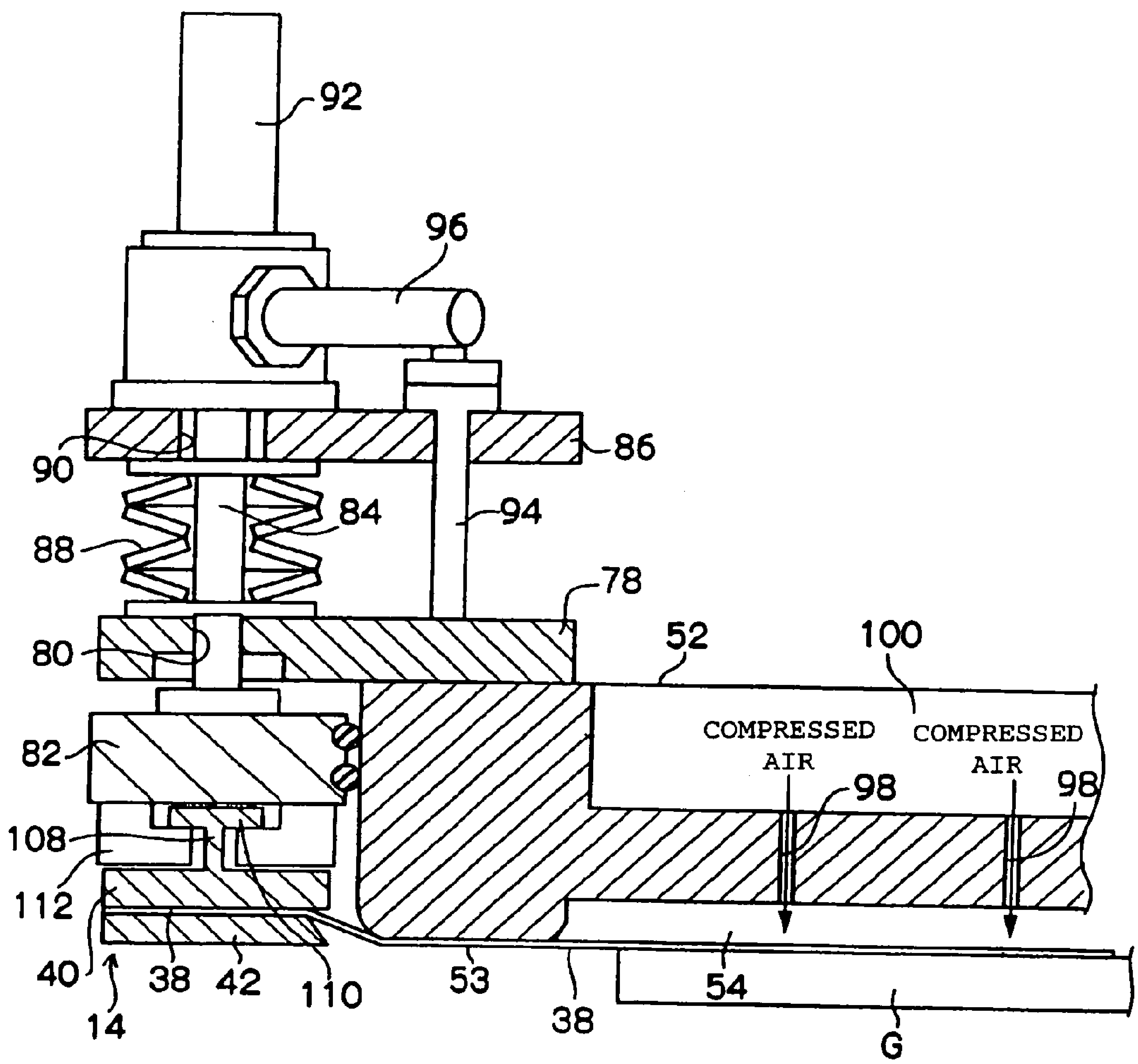


Fig. 5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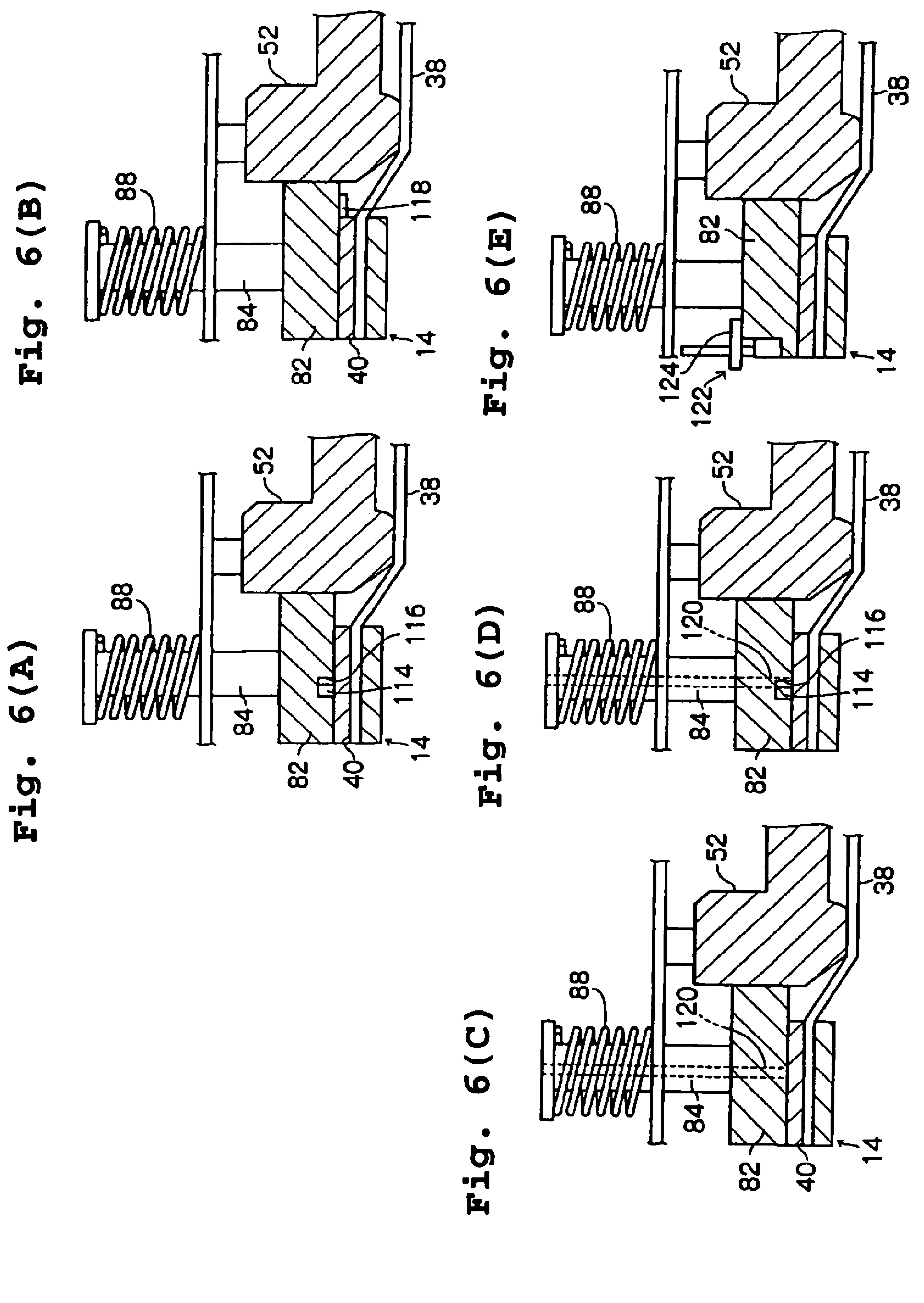
Fig. 6(A)
Fig. 6(B)
Fig. 6(C)
Fig. 6(D)
Fig. 6(E)
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Fig. 7(B)

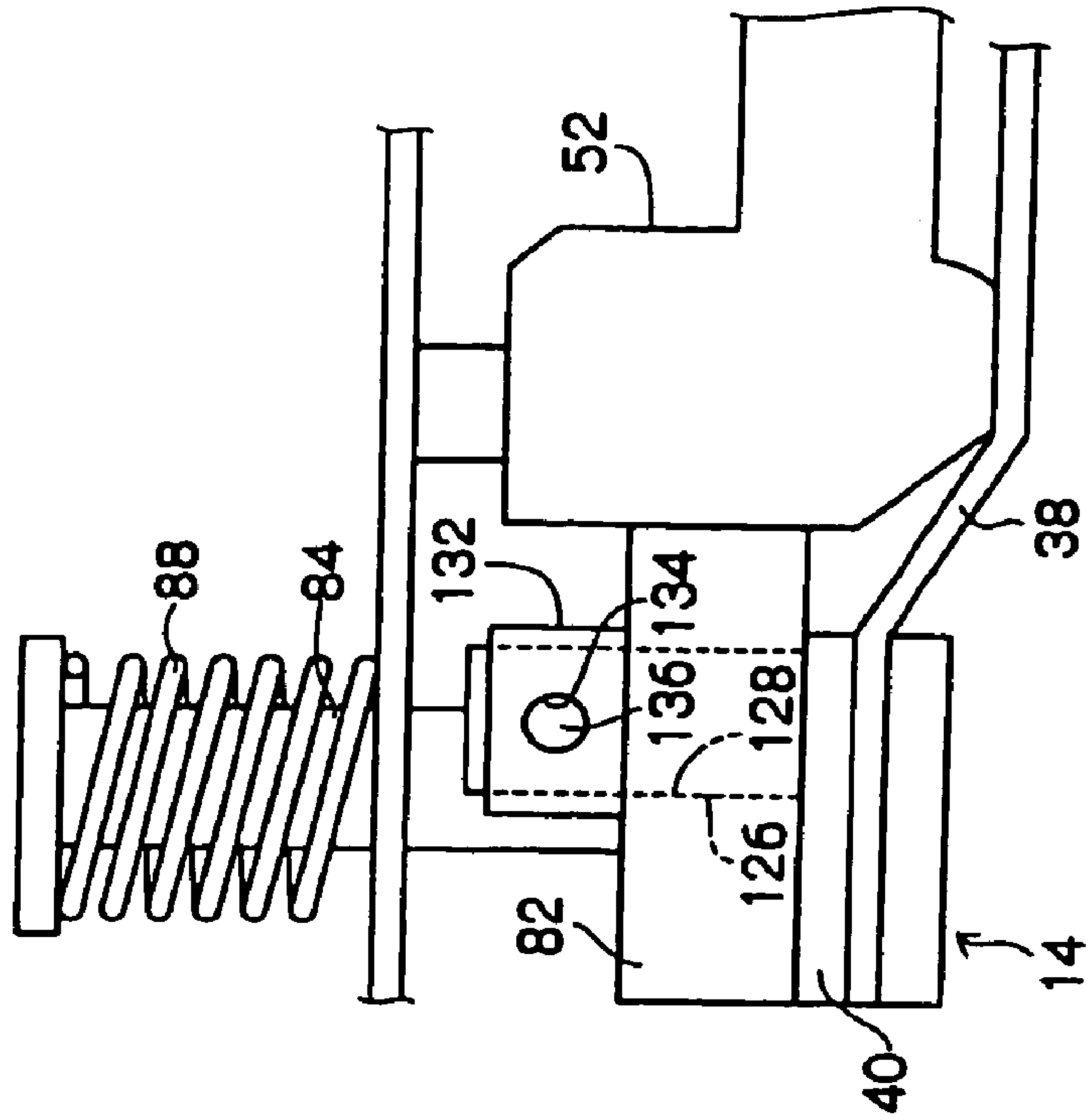
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Fig. 7(A)

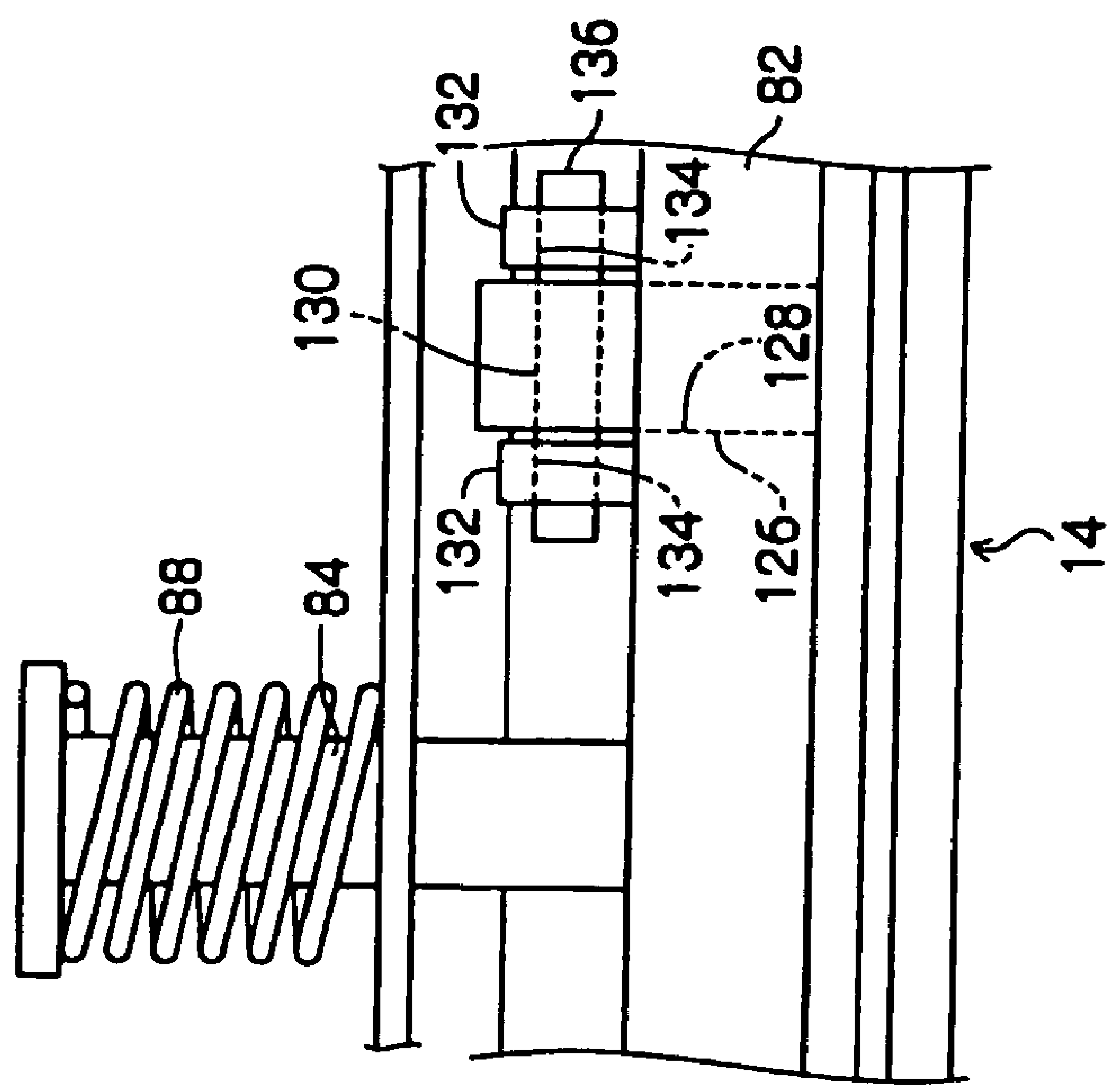
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Fig. 8

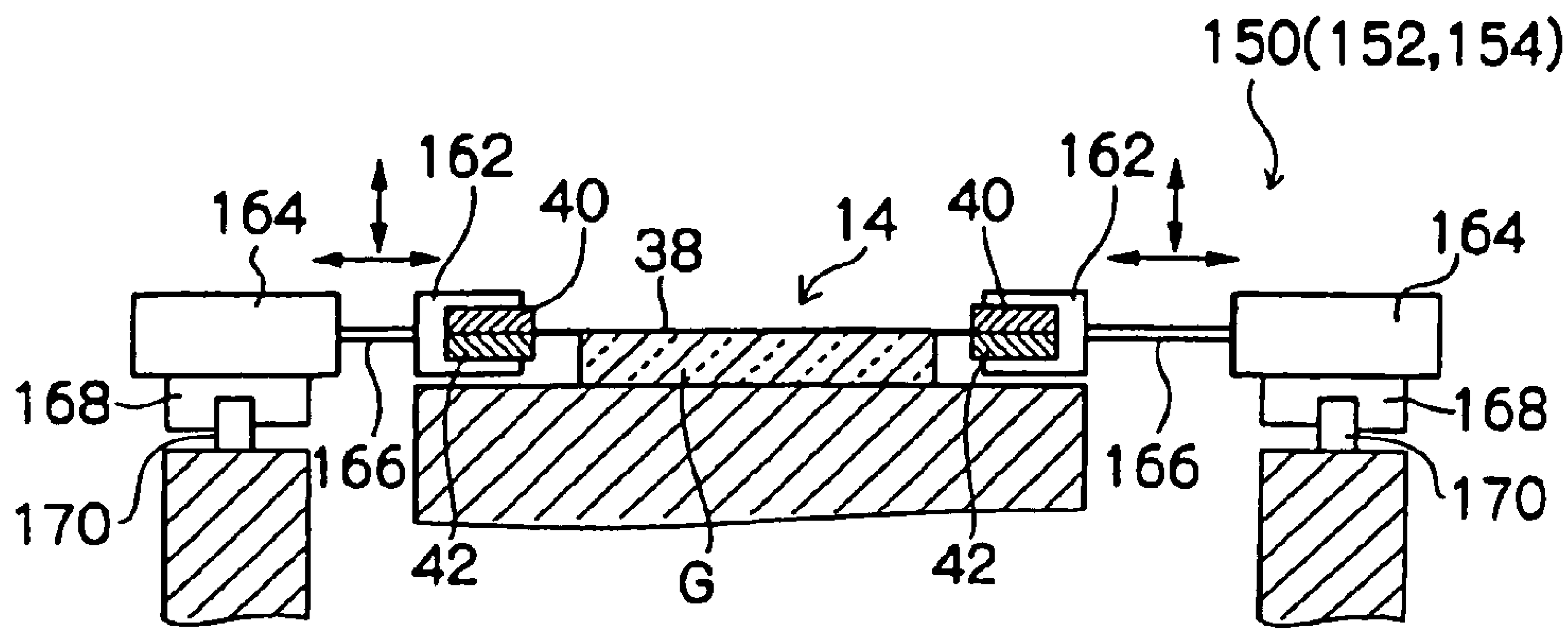
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Fig. 9(a)

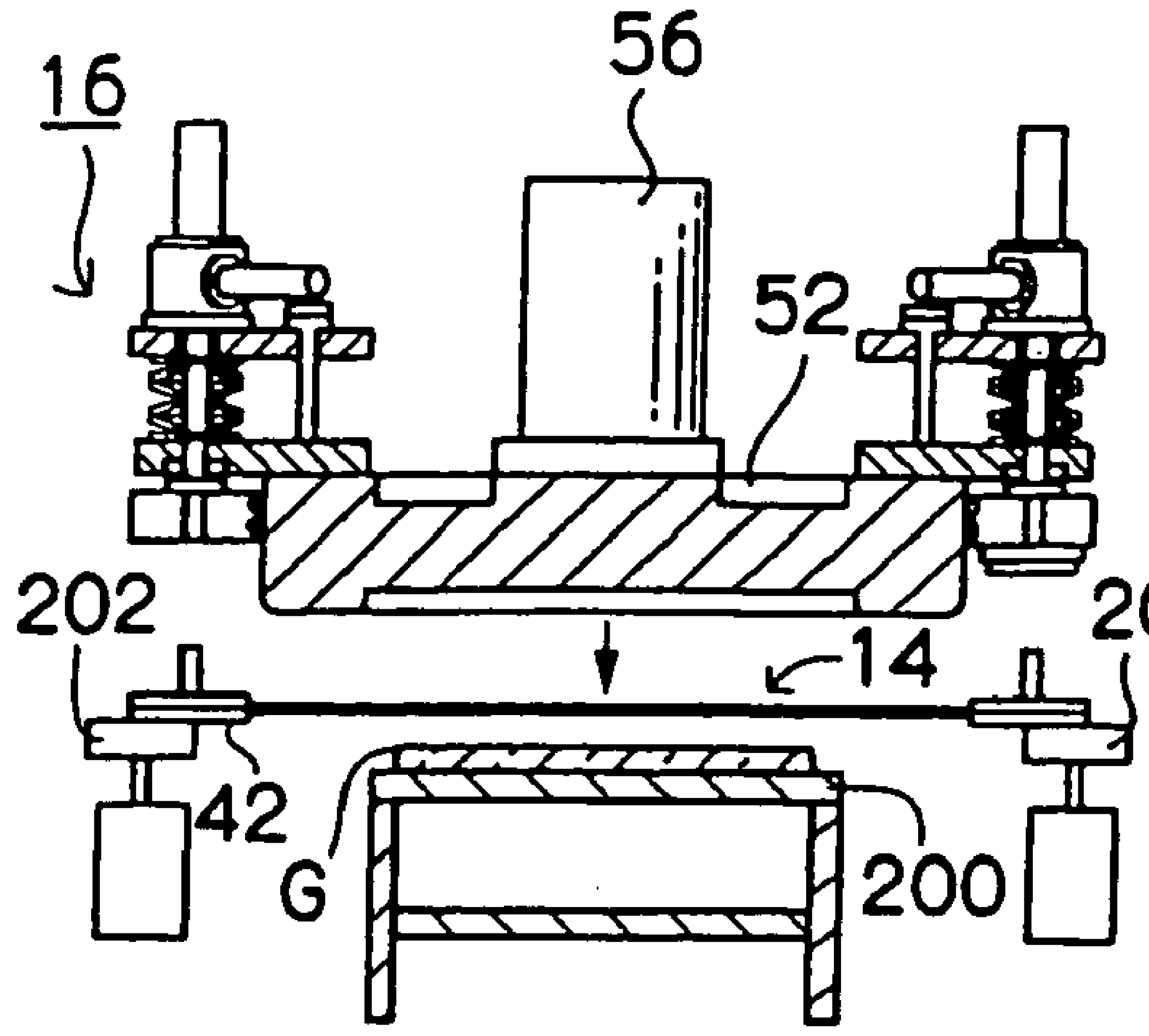


Fig. 9(b)

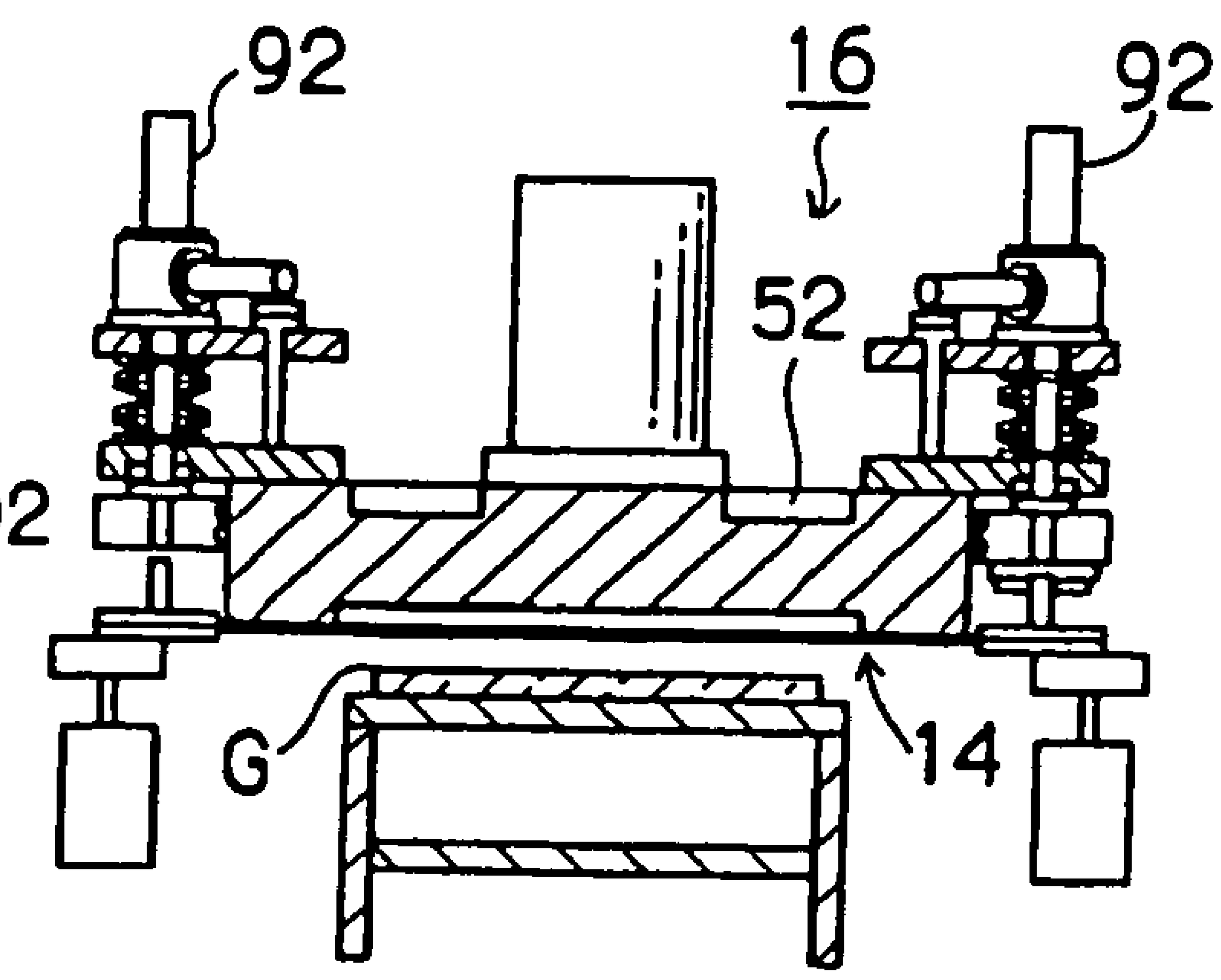


Fig. 9(c)

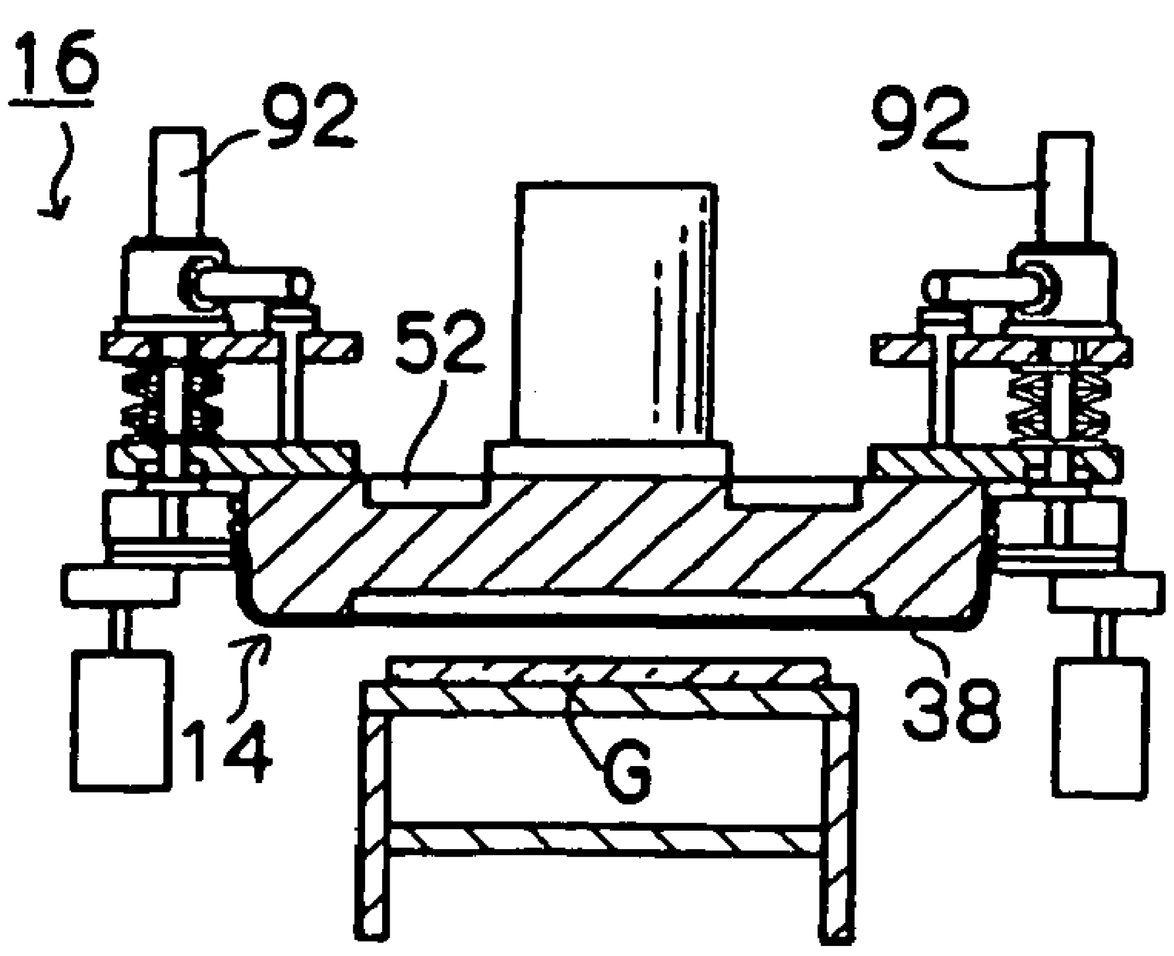


Fig. 9(d)

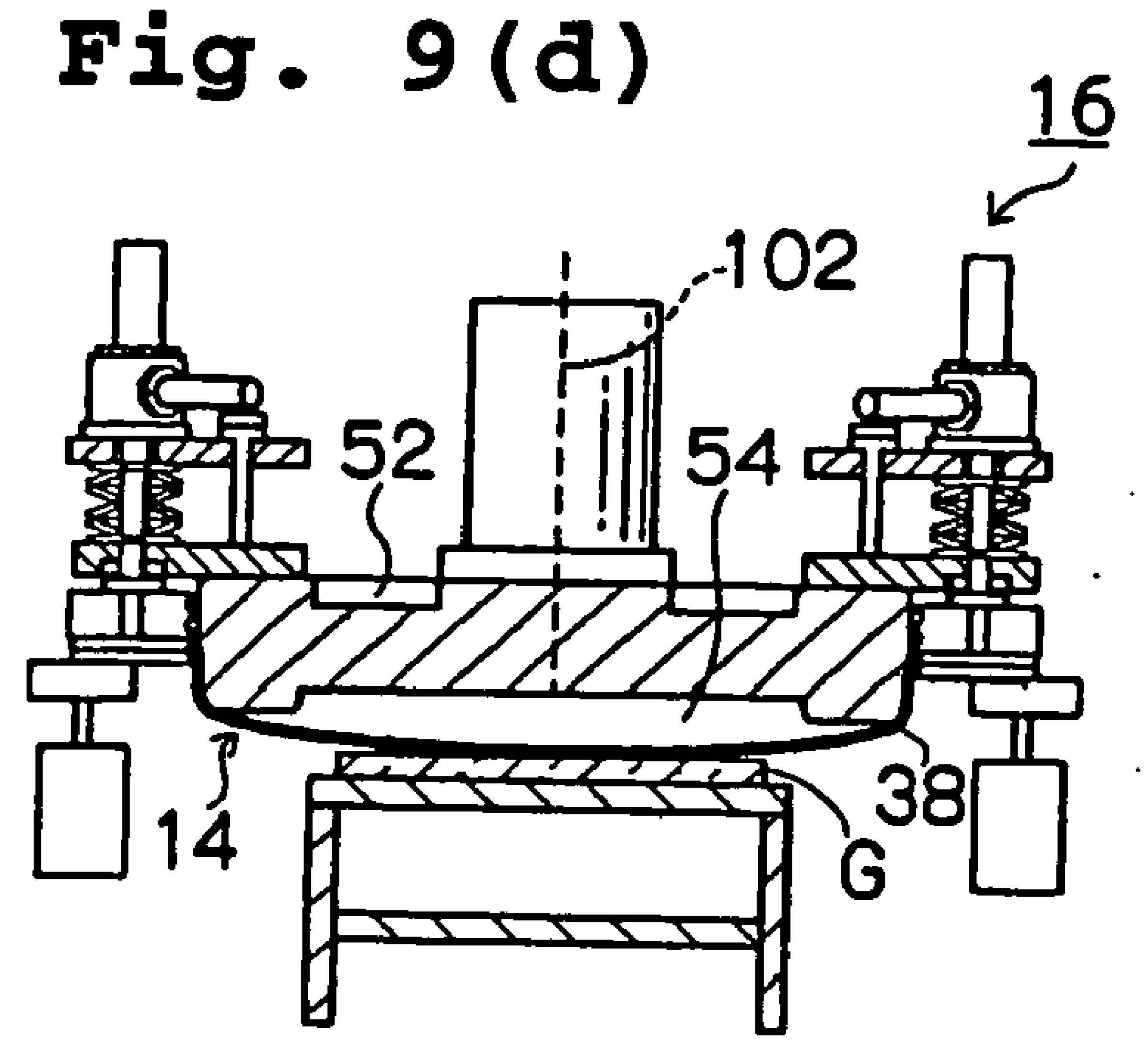


Fig. 9(e)

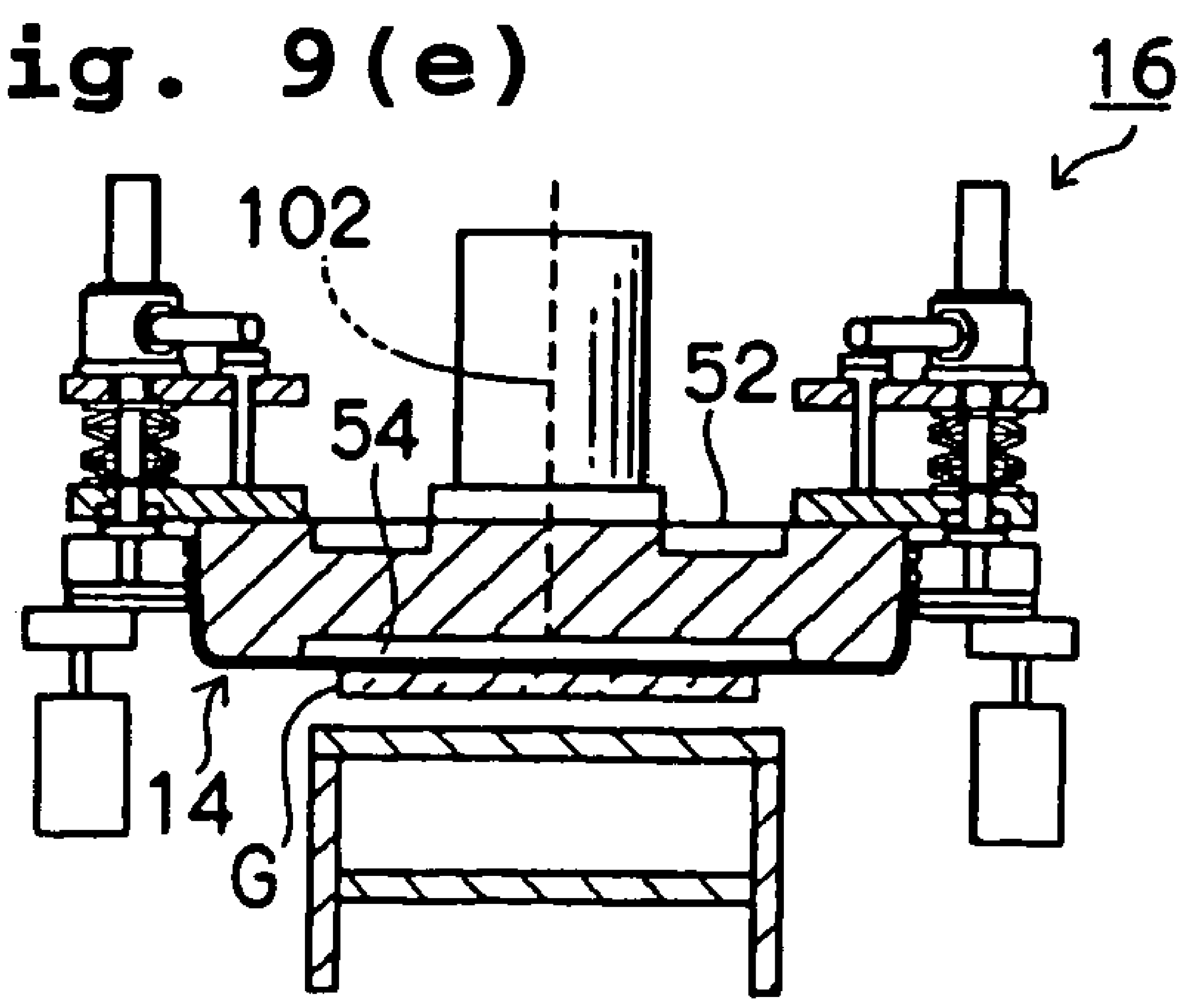


Fig. 10(a)

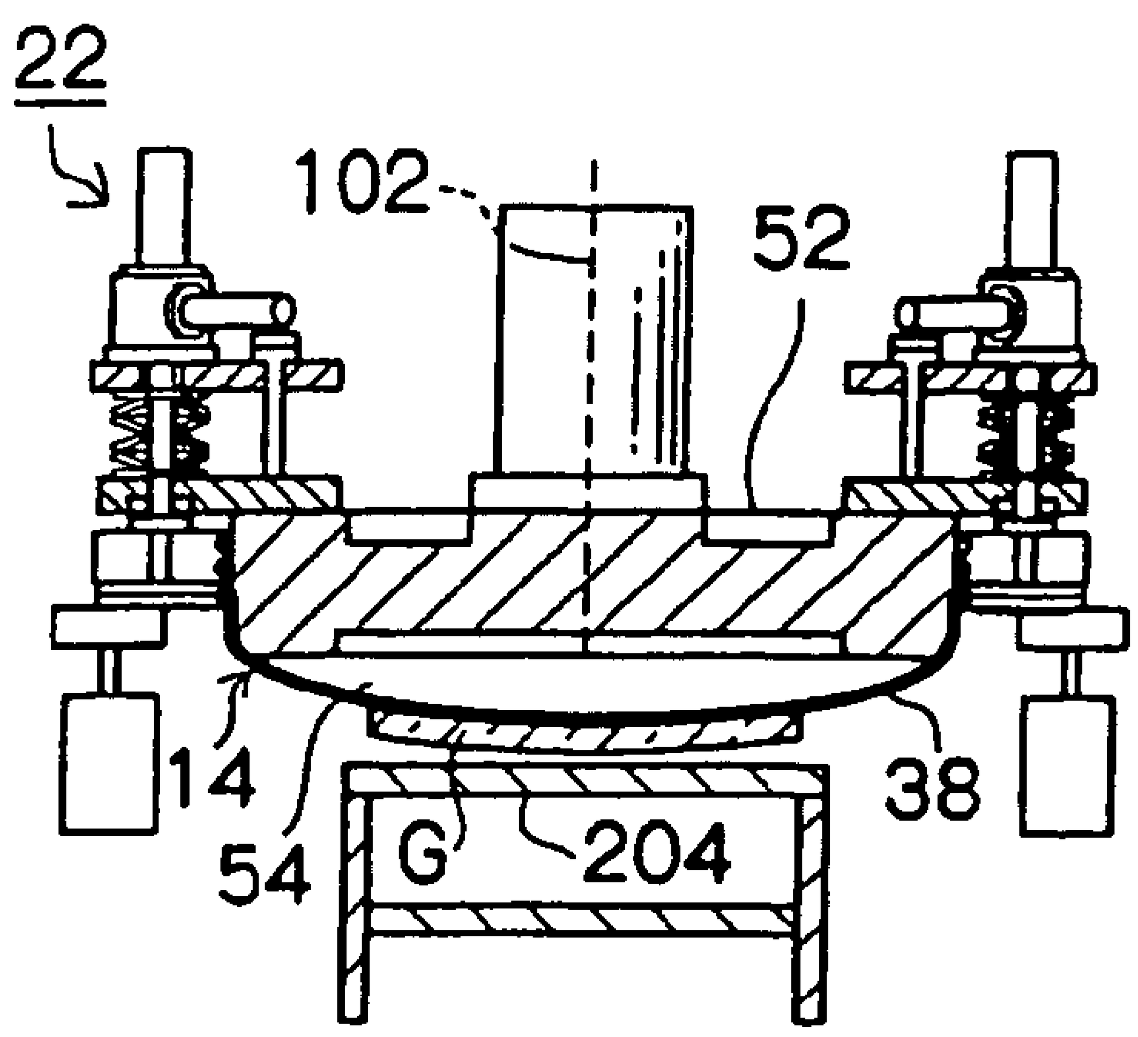


Fig. 10(b)

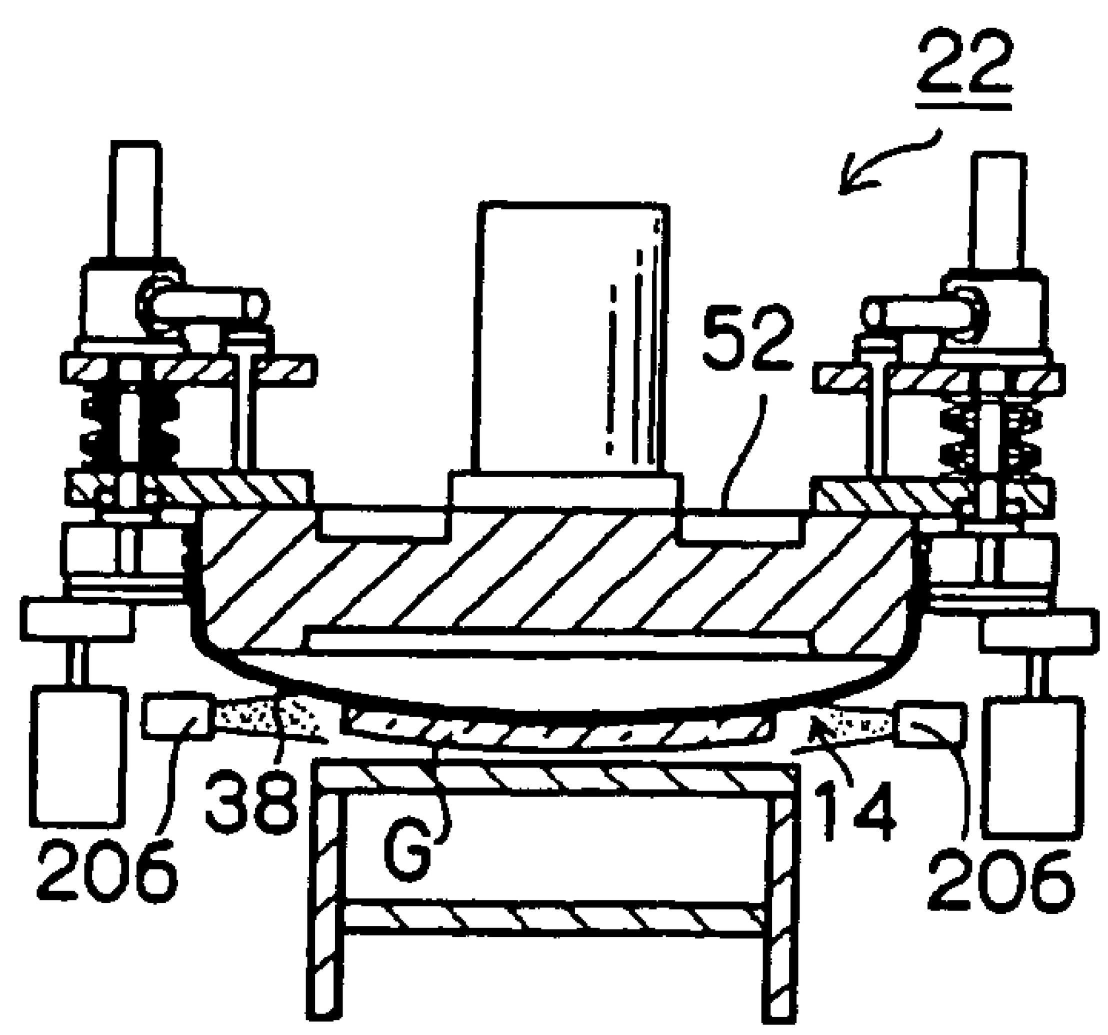


Fig. 10(c)

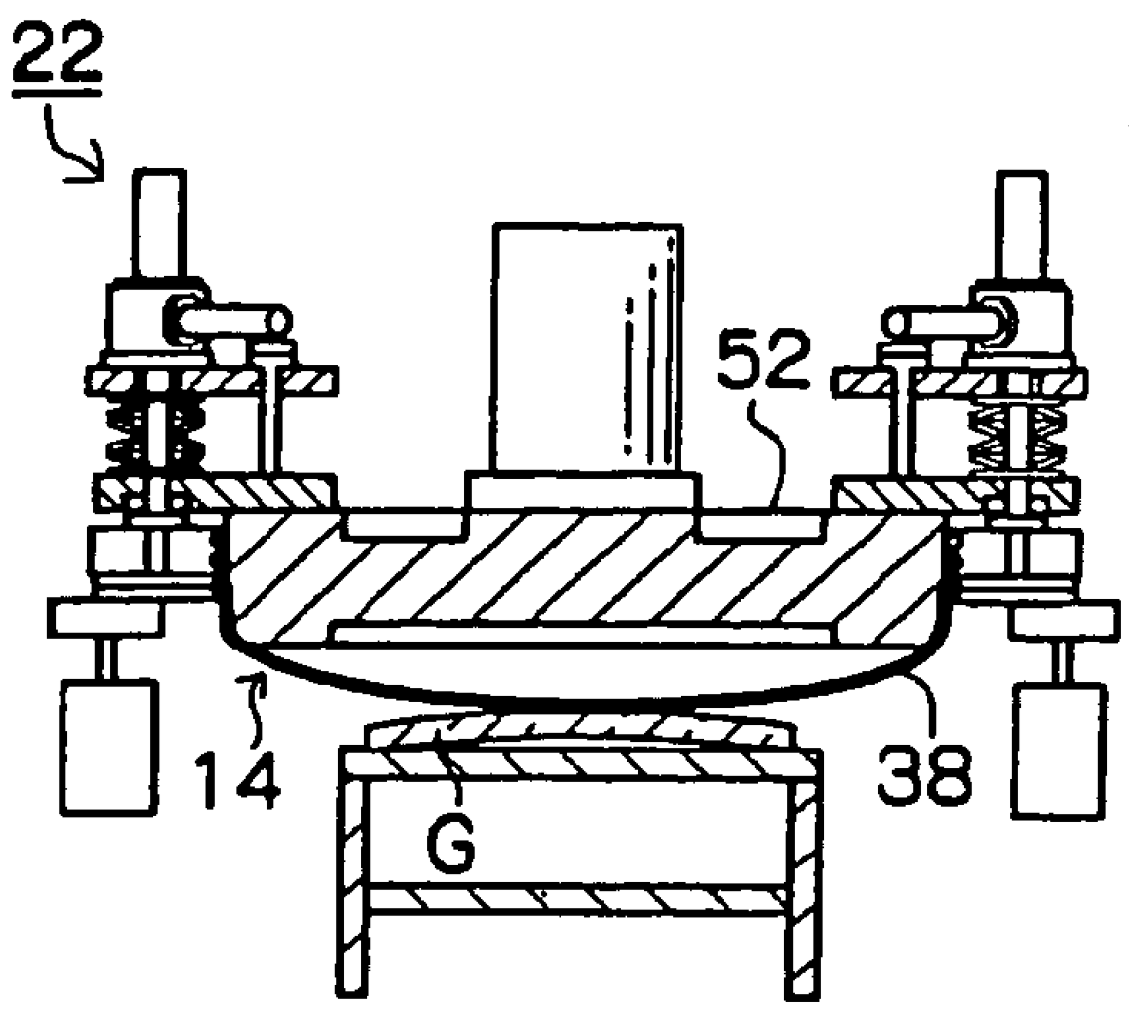


Fig. 10(d)

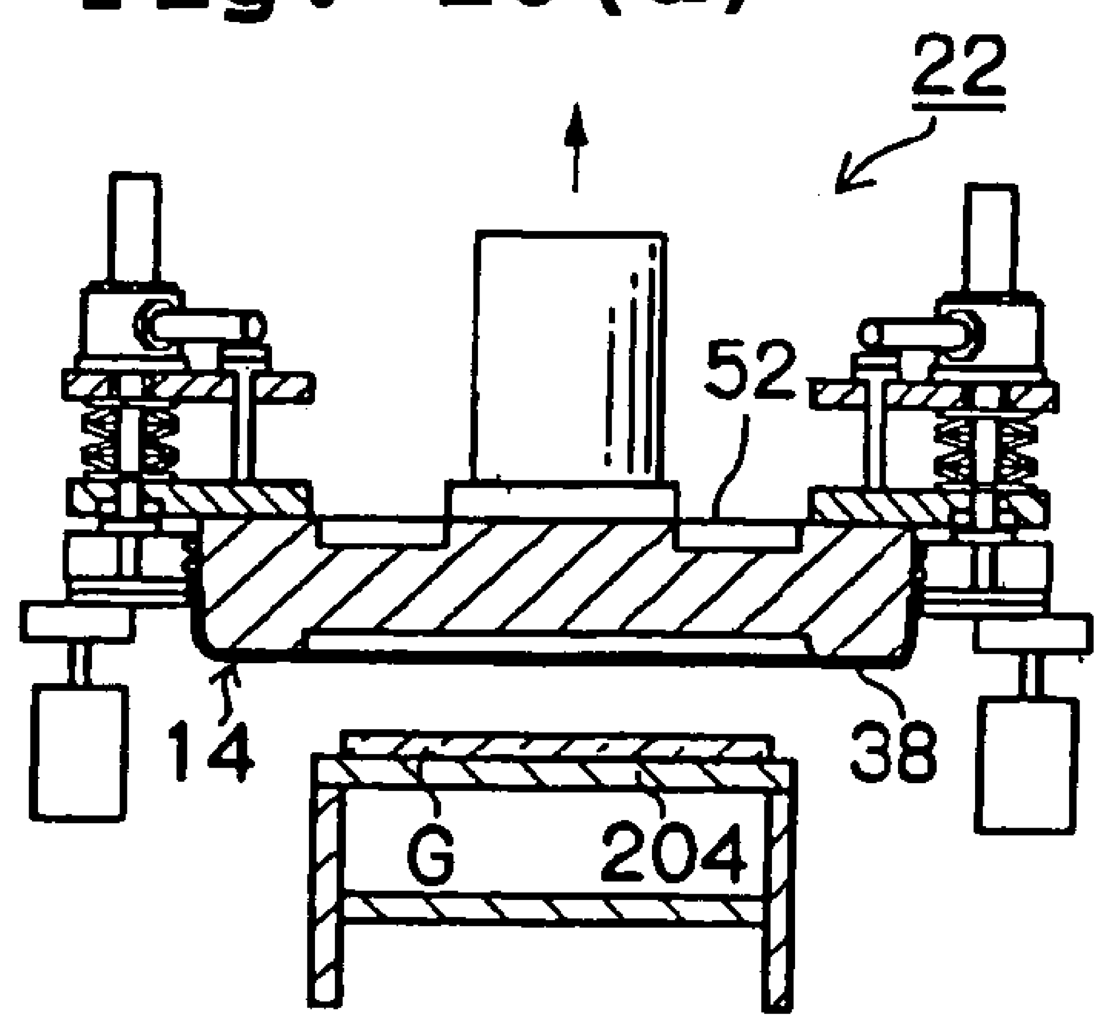
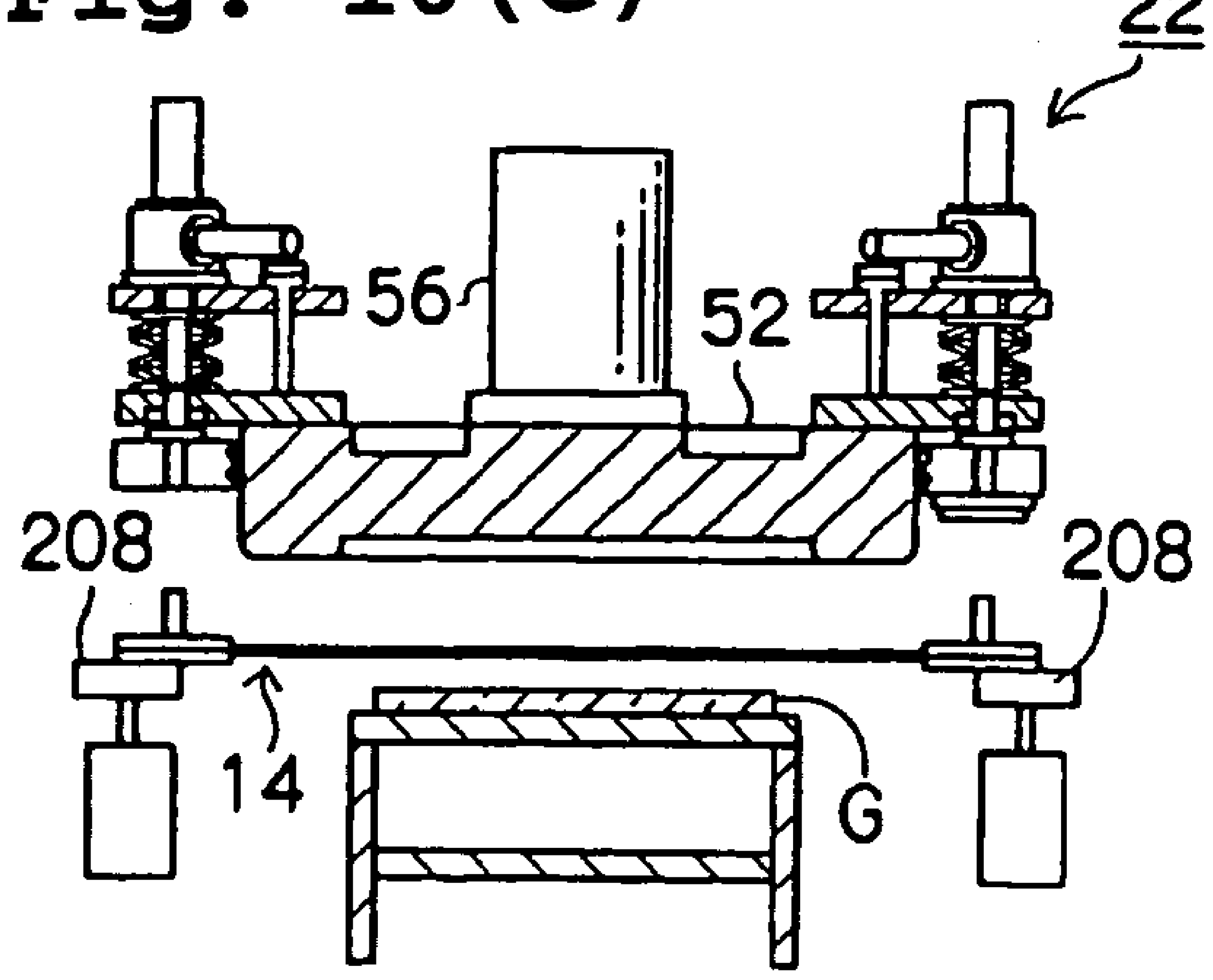


Fig. 10(e)



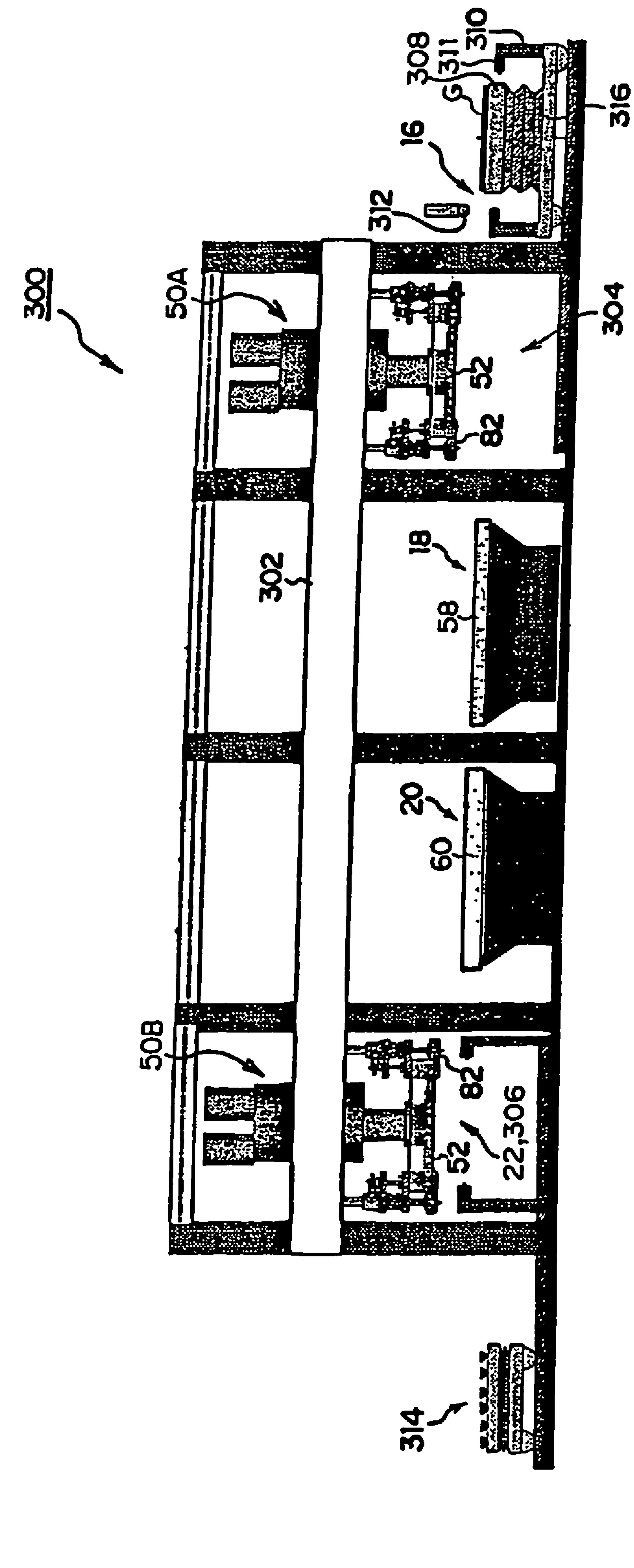

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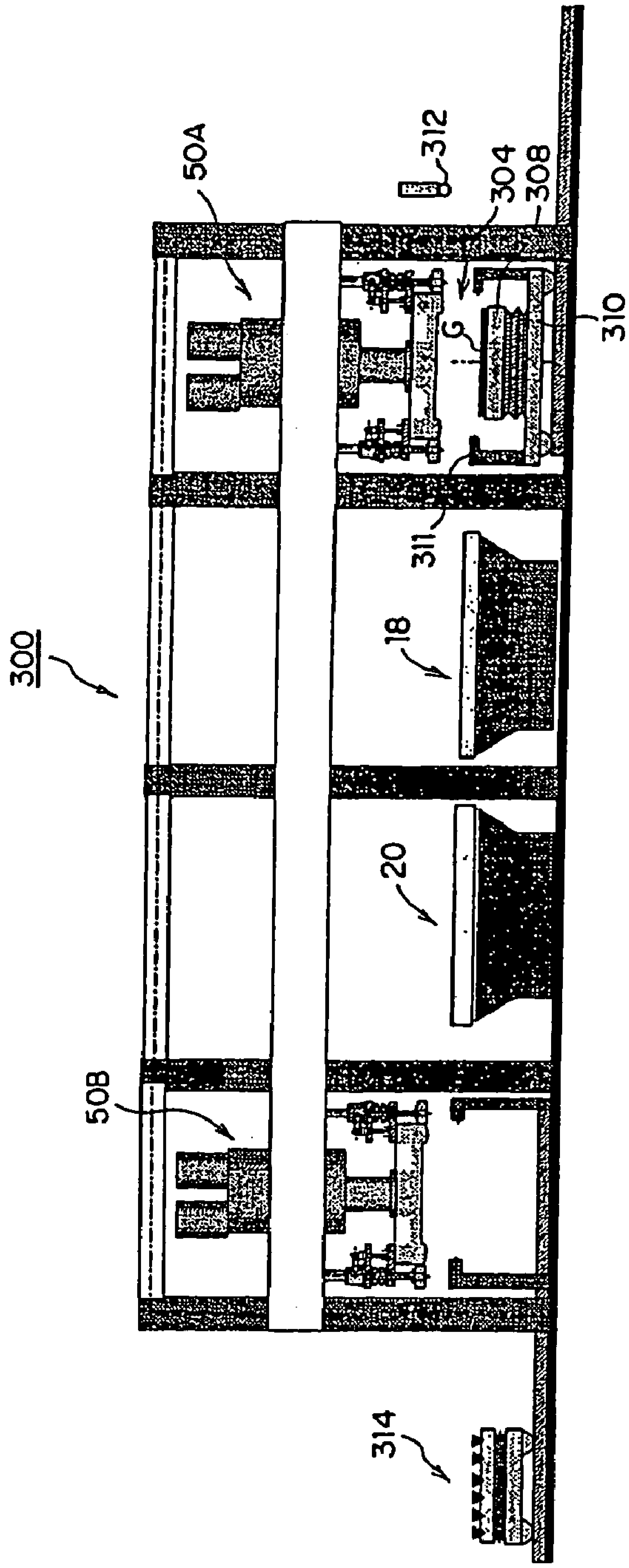
Fig. 11



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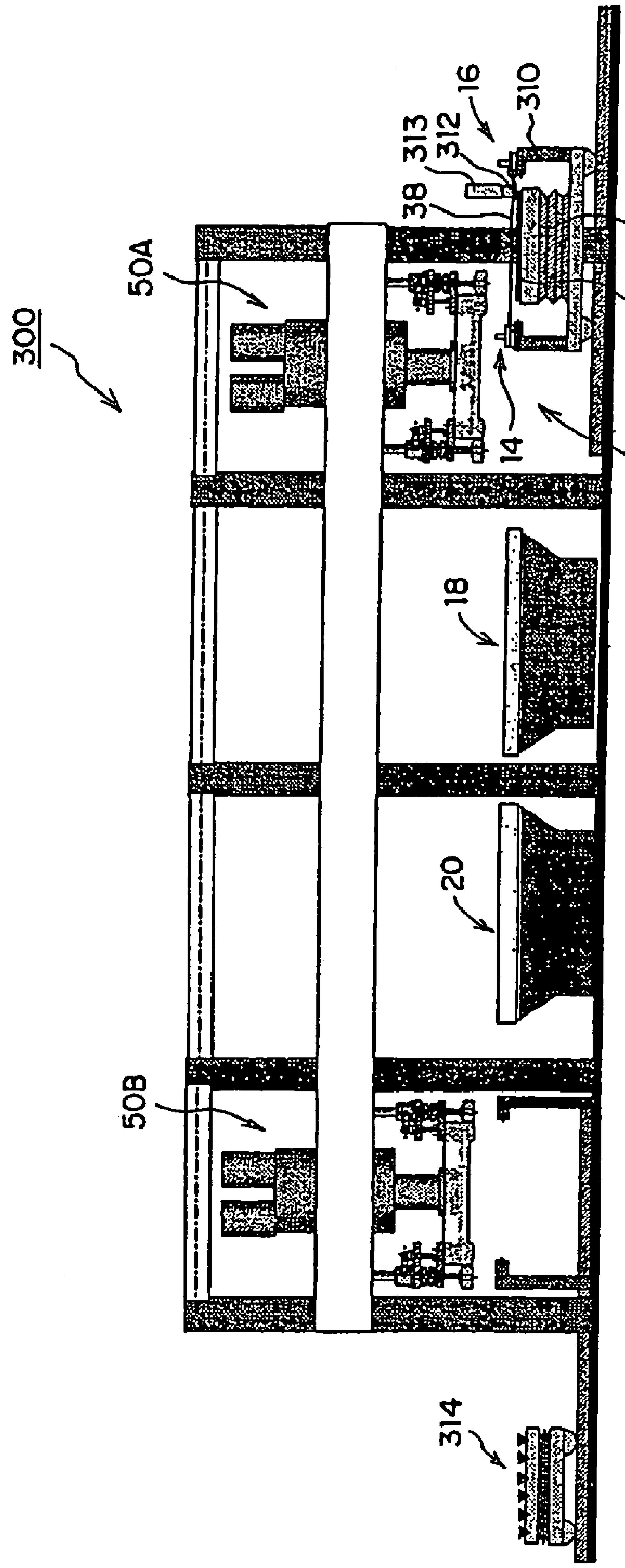

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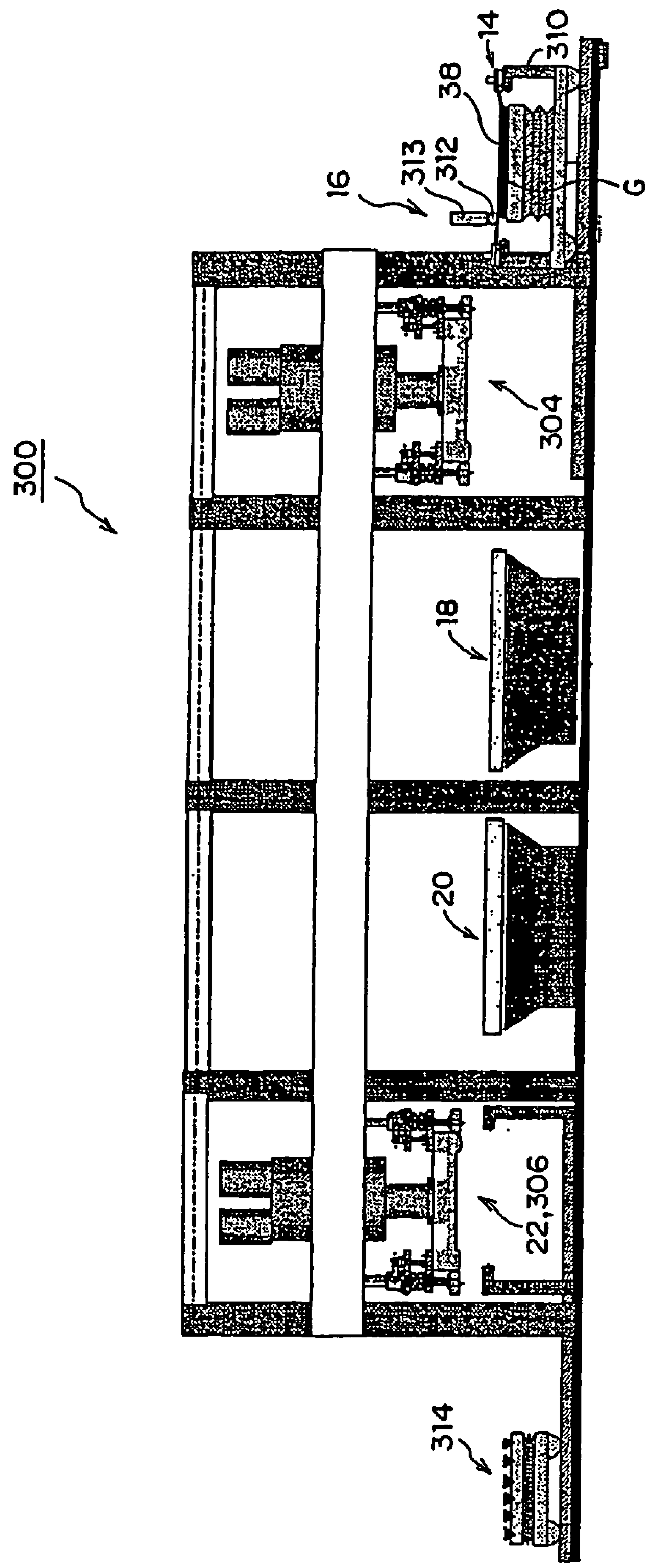

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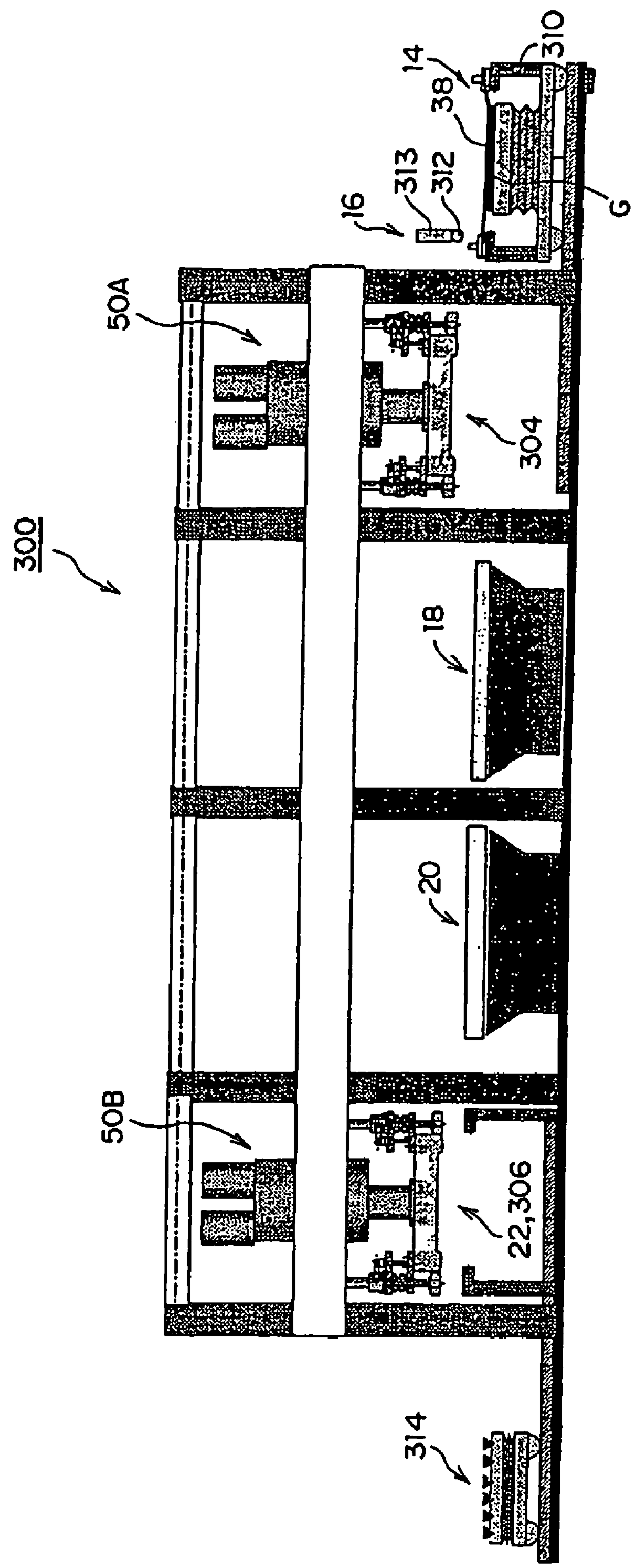
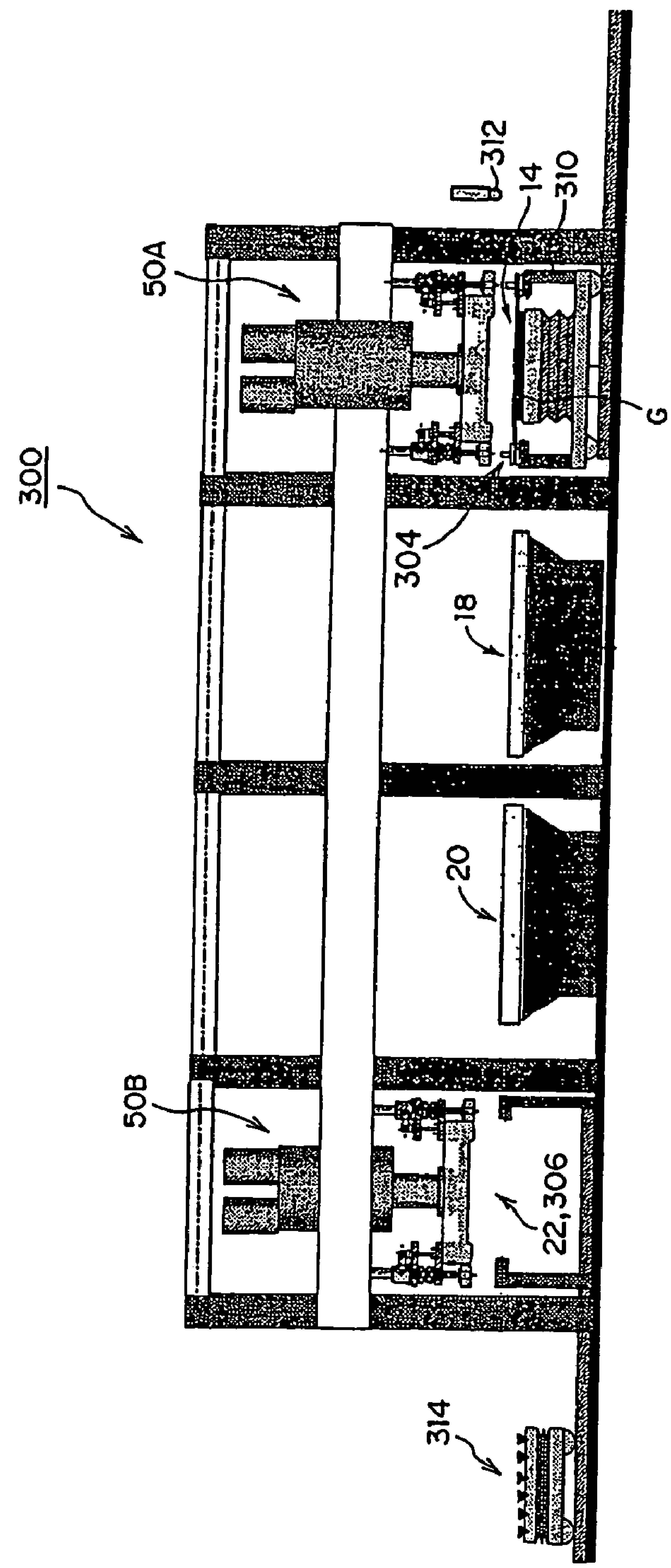
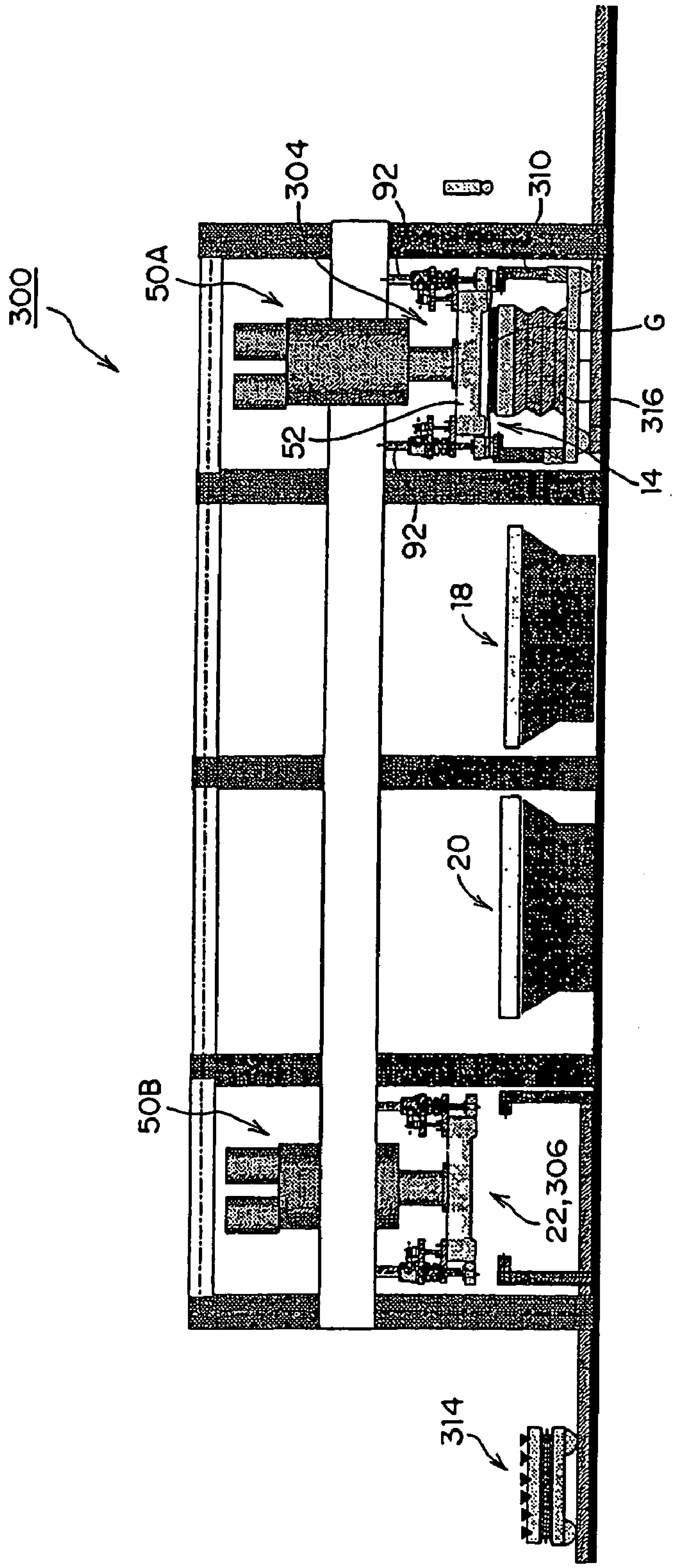


Fig. 15

Fig. 16





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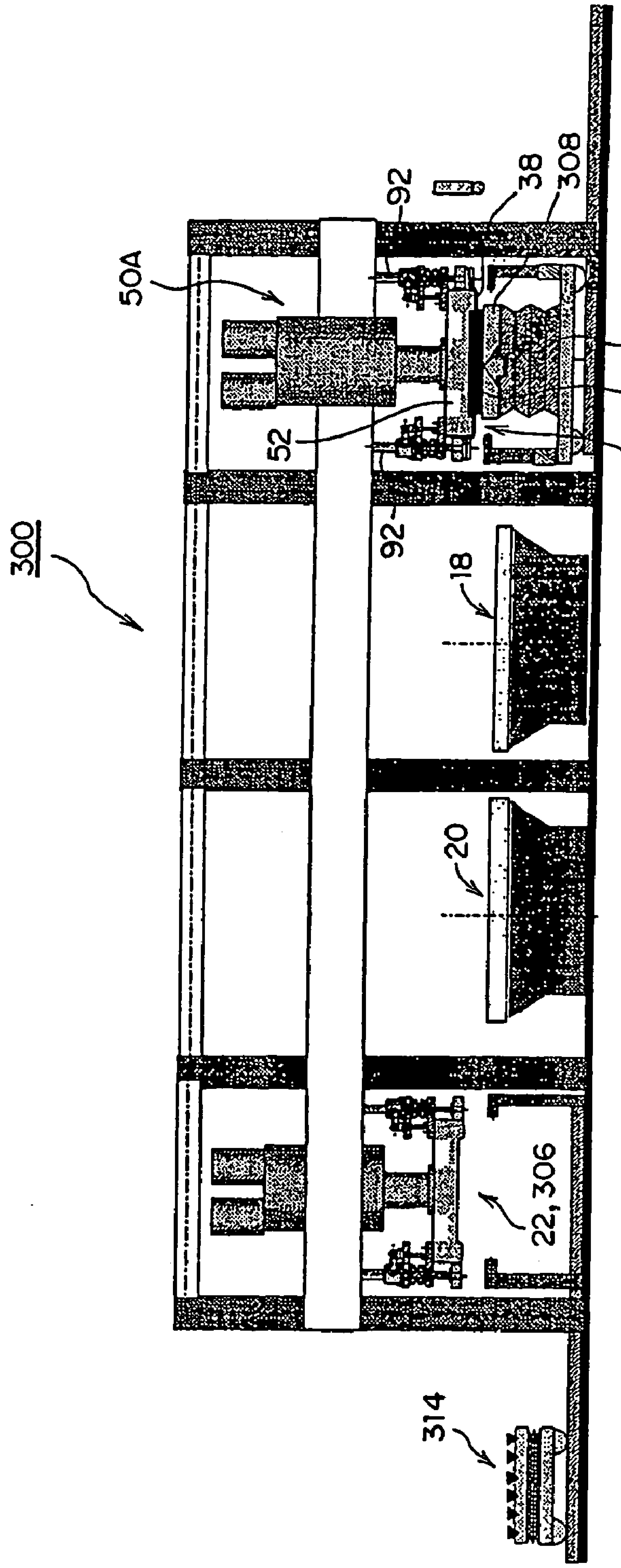

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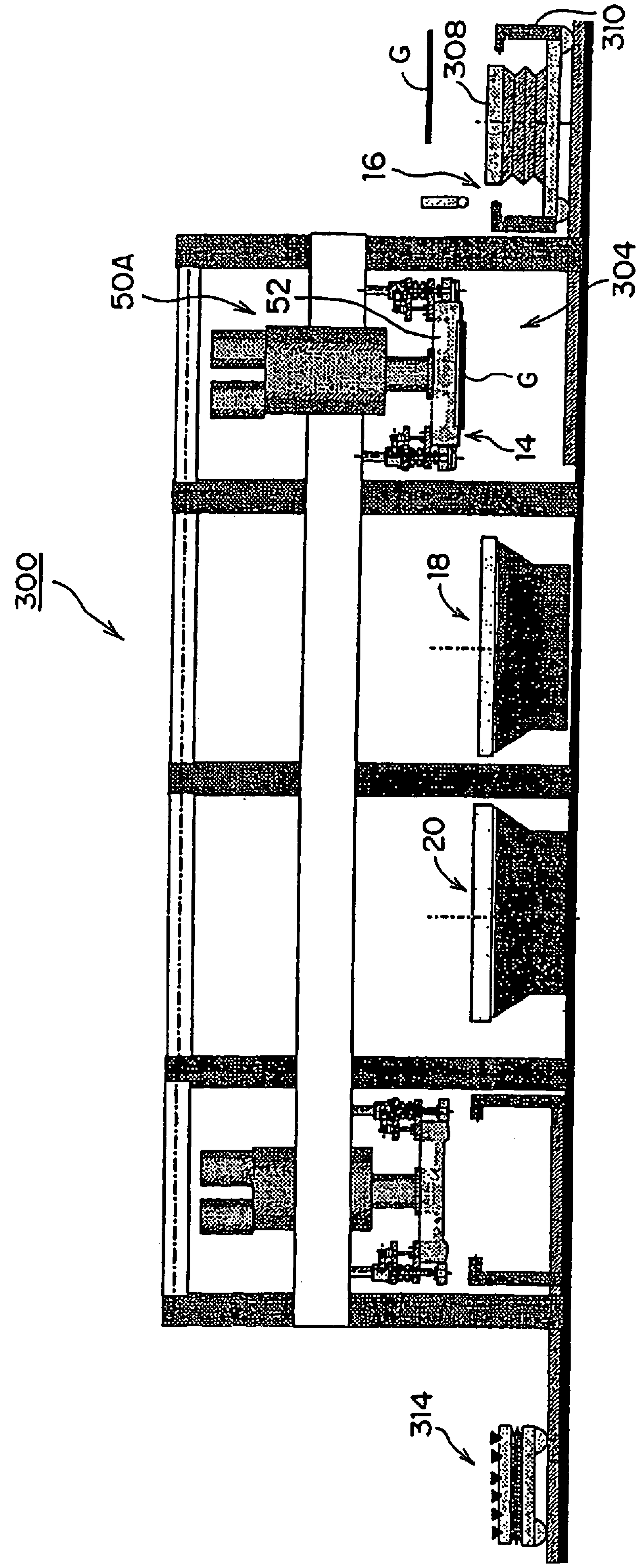

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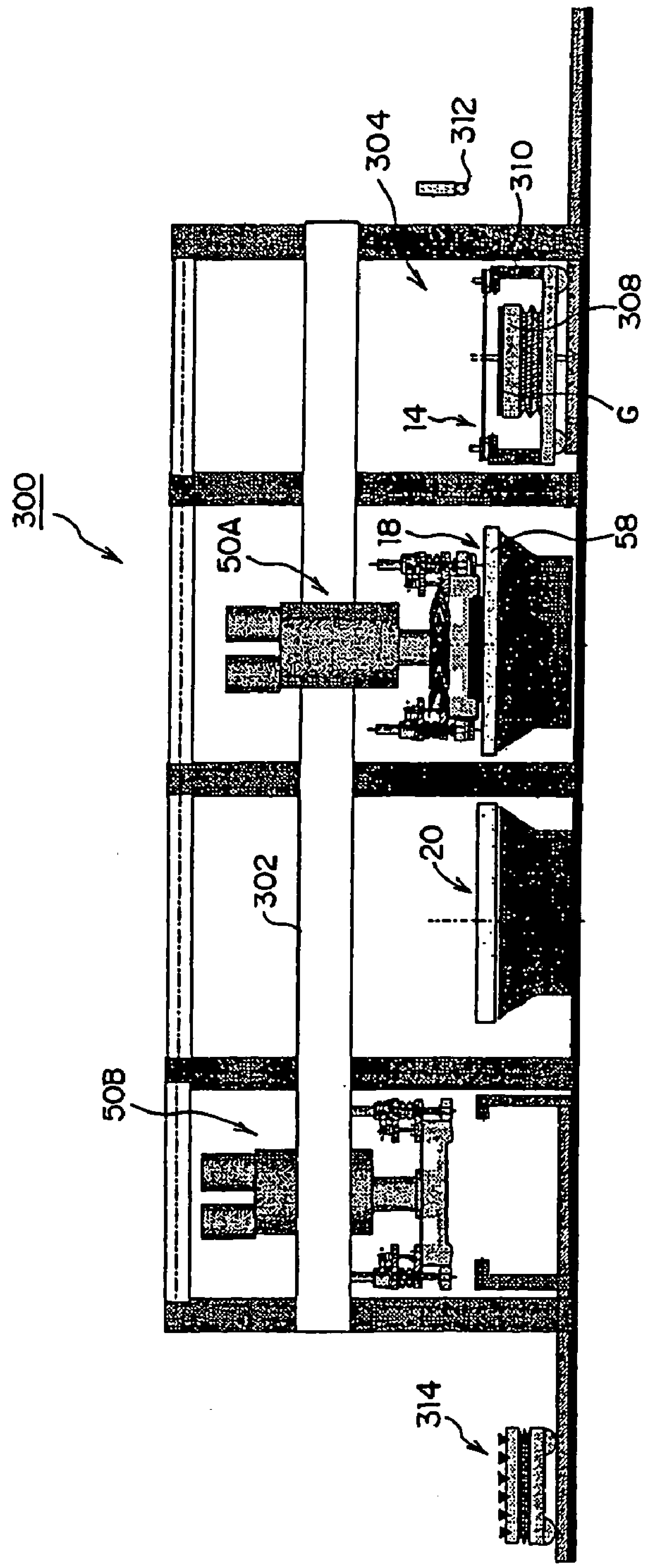
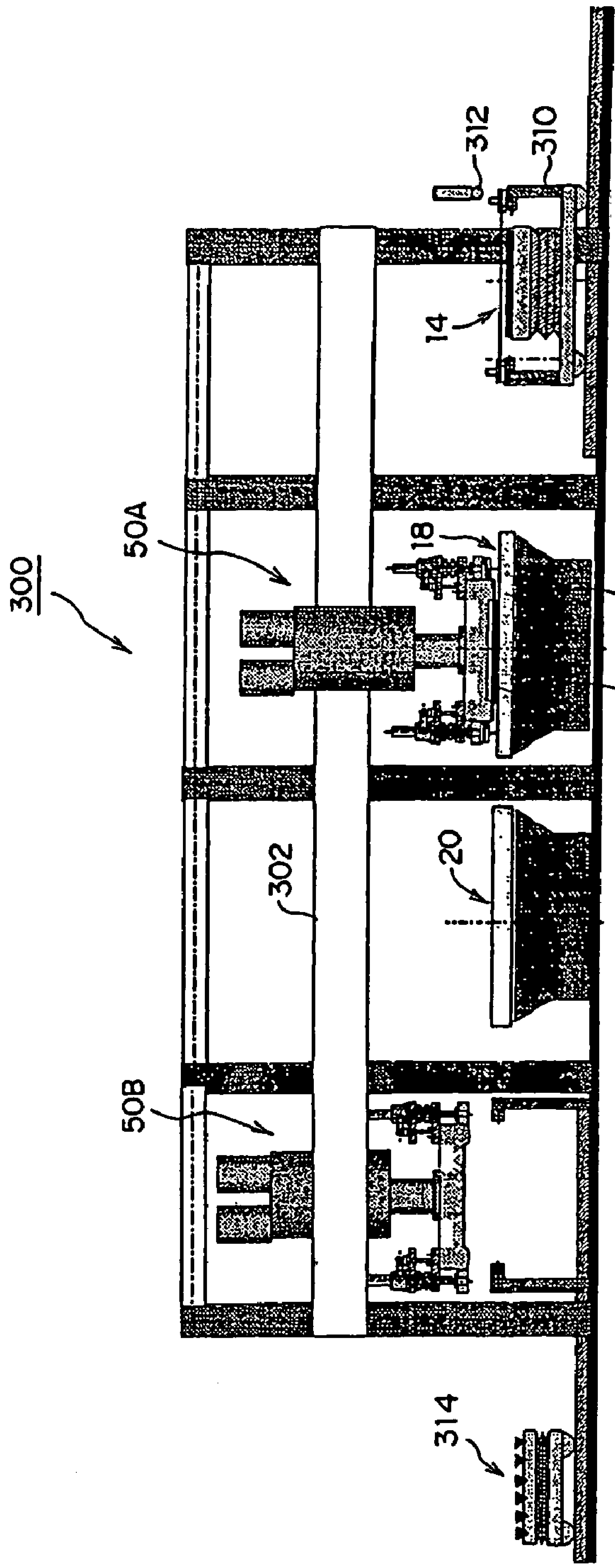


Fig. 20



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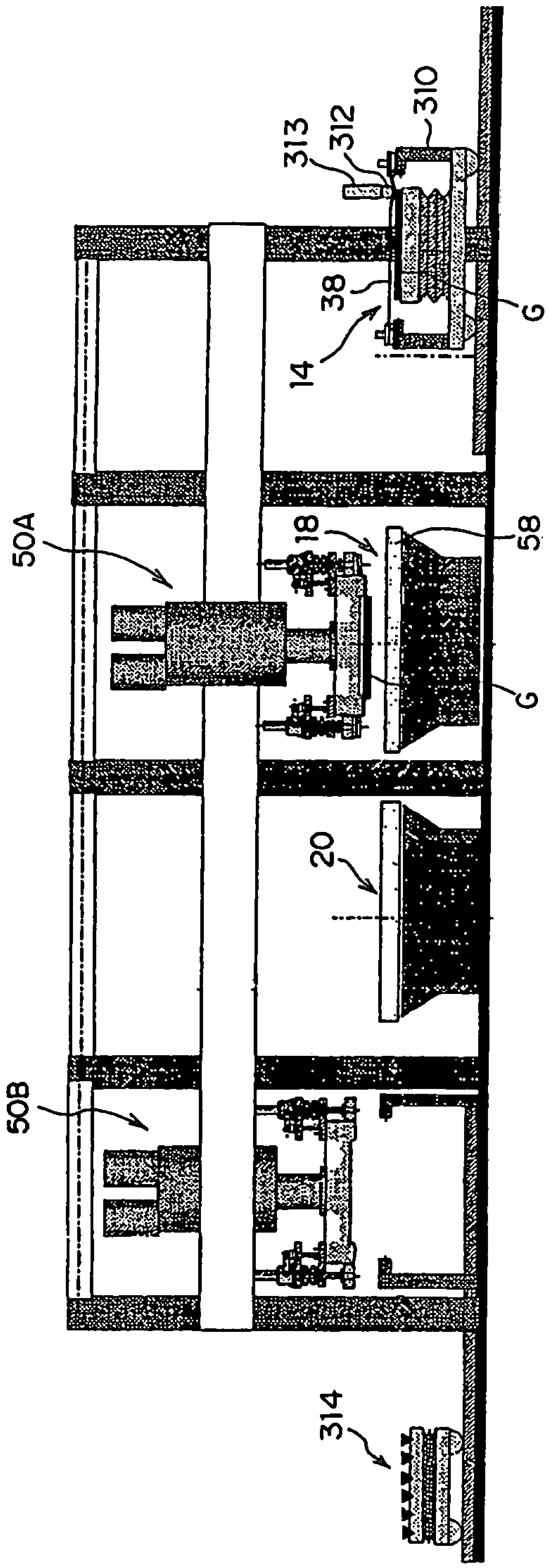

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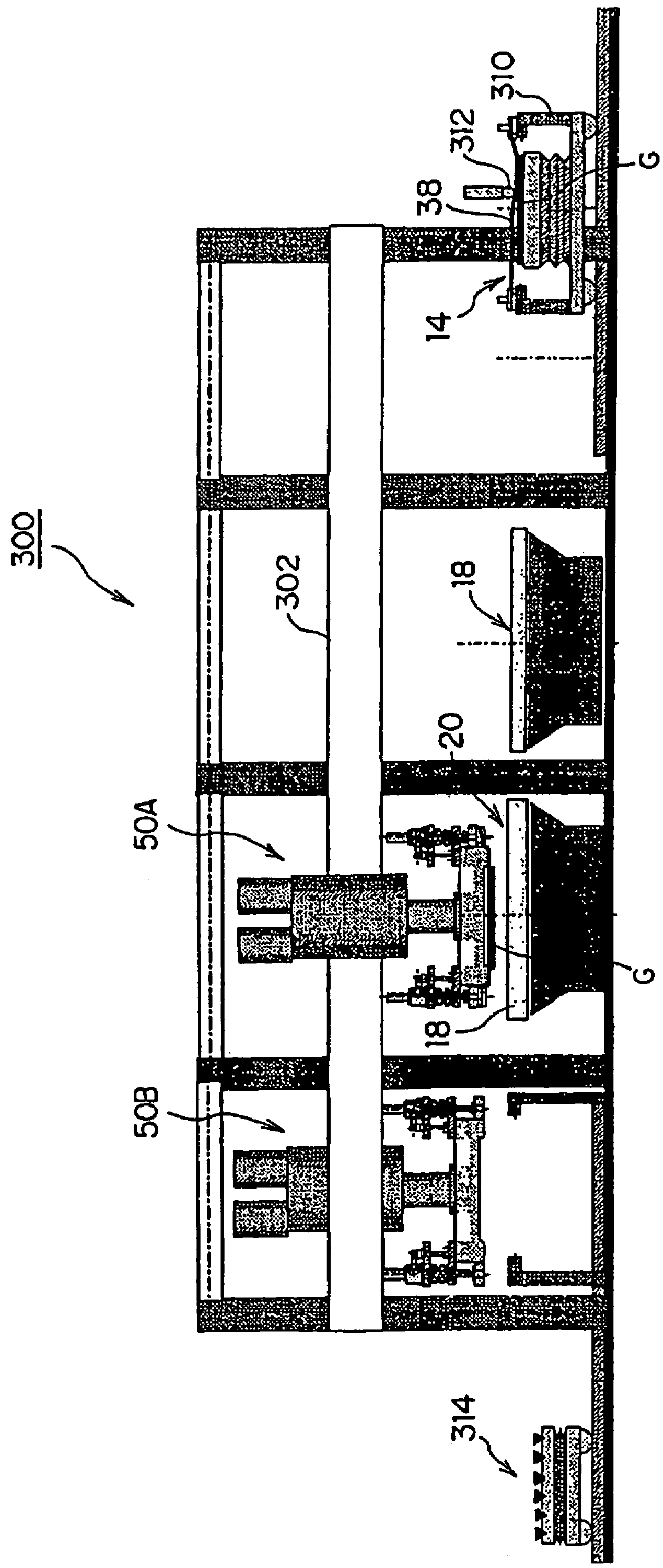


Fig. 23

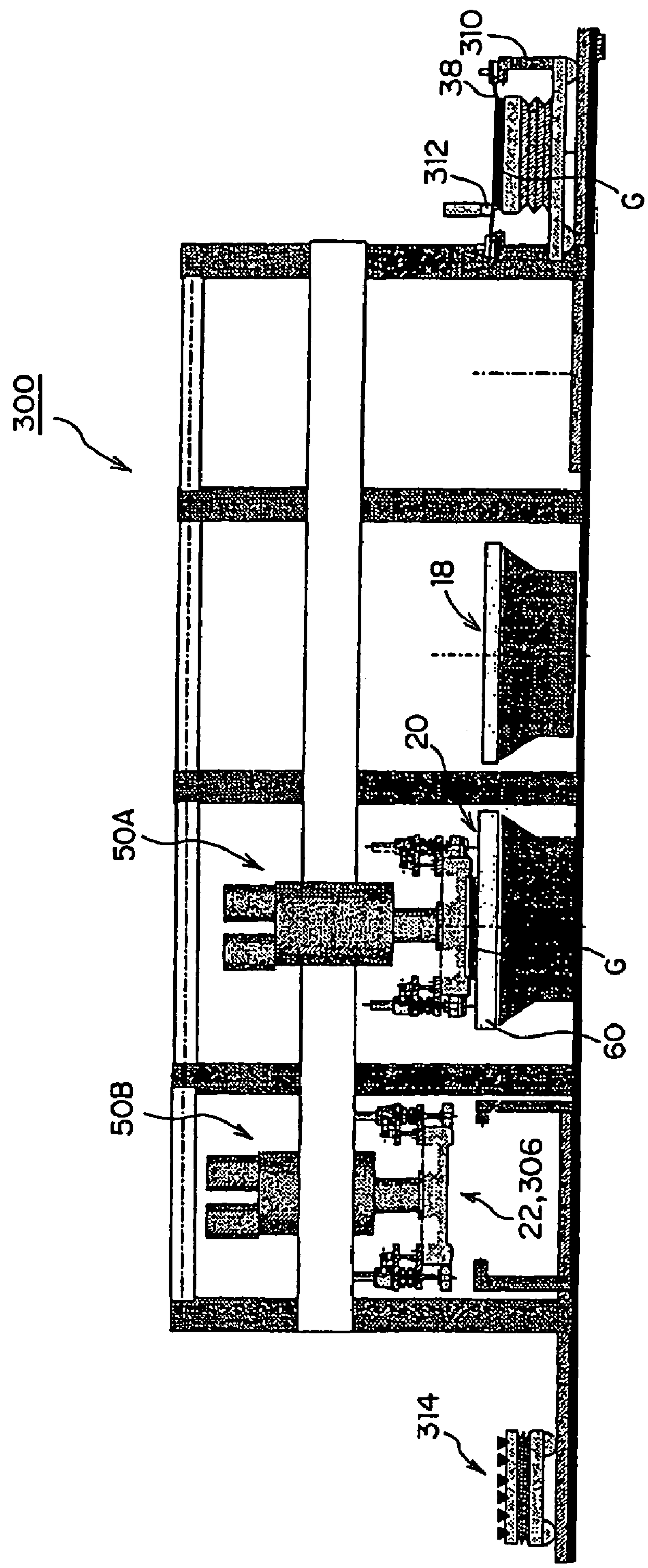


Fig. 24

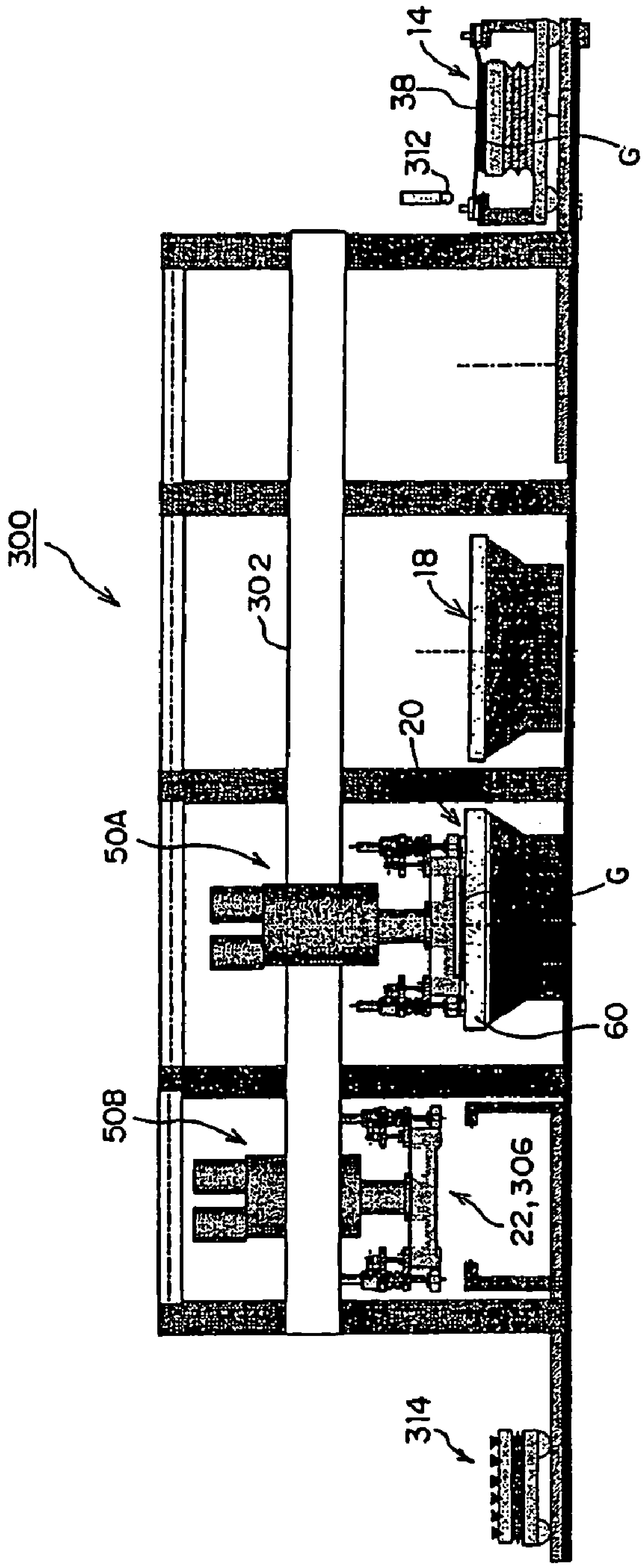
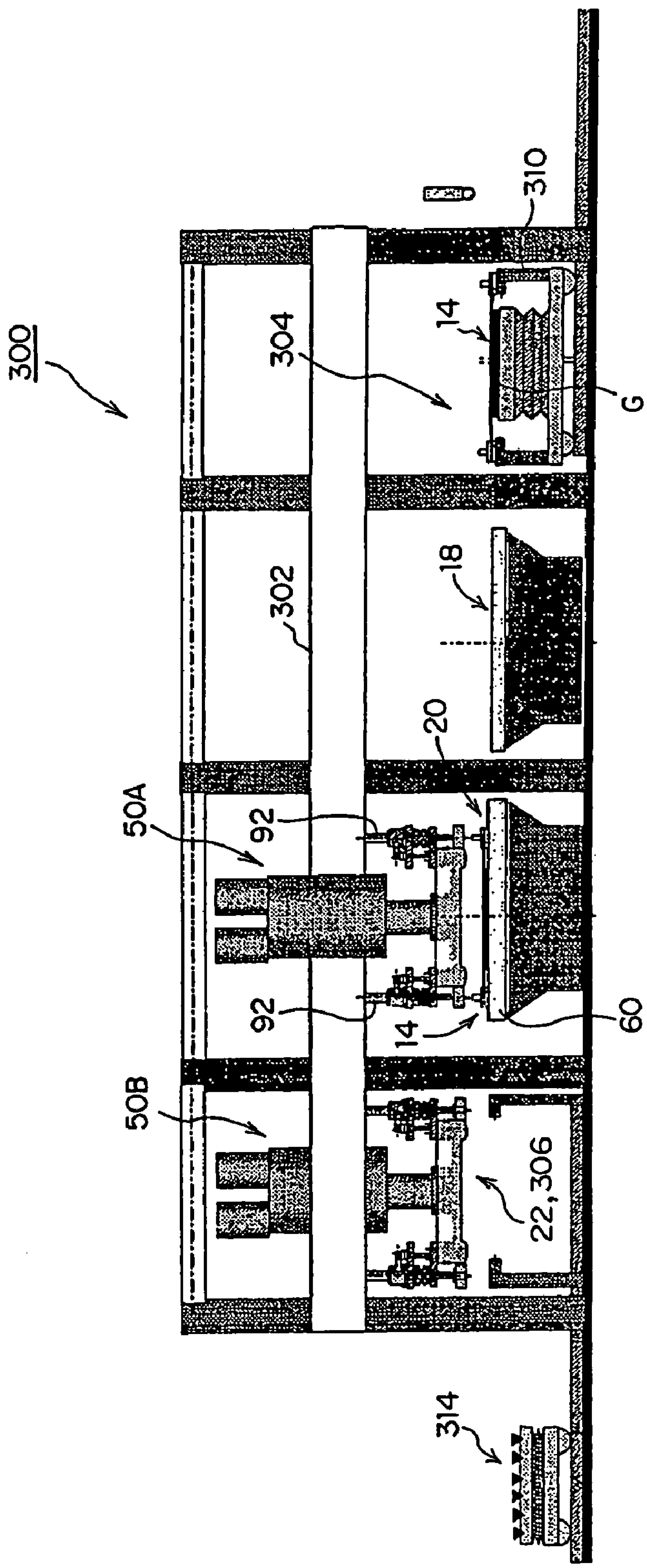
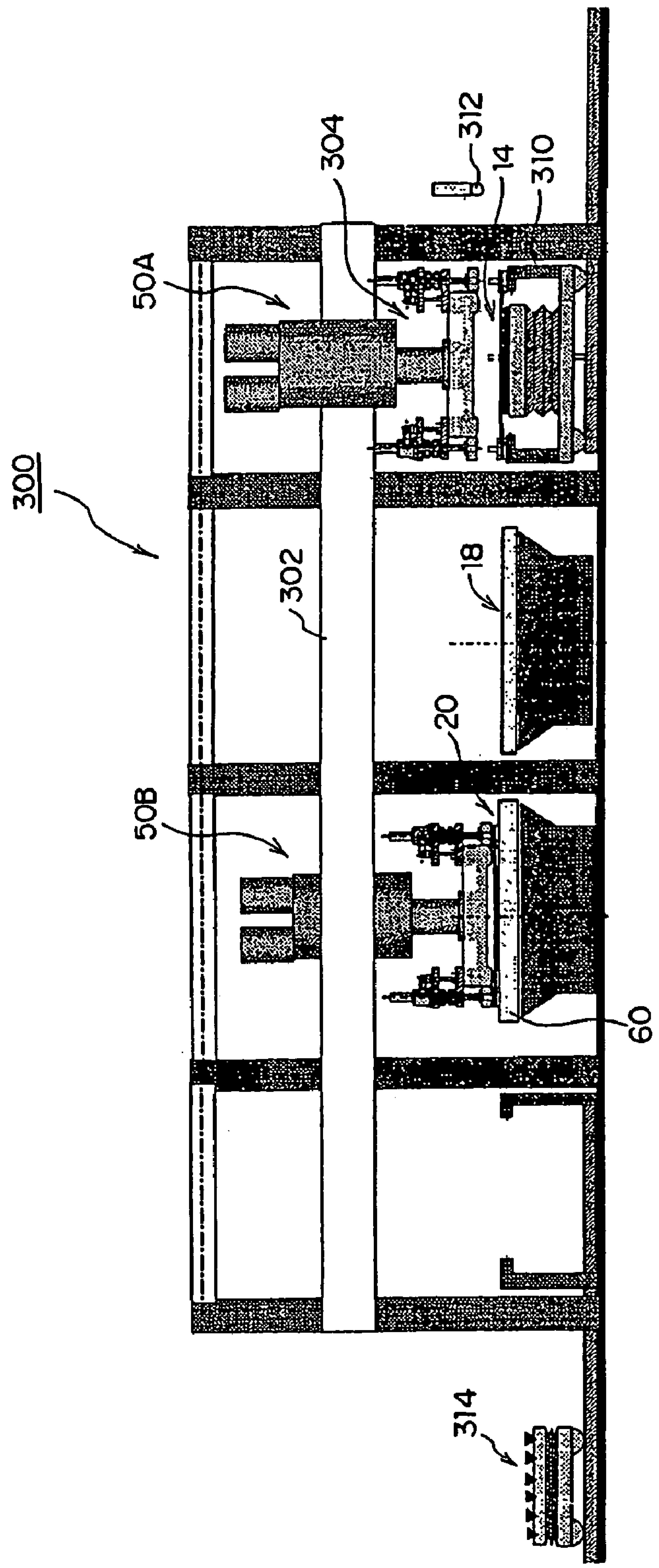


Fig. 25

Fig. 26





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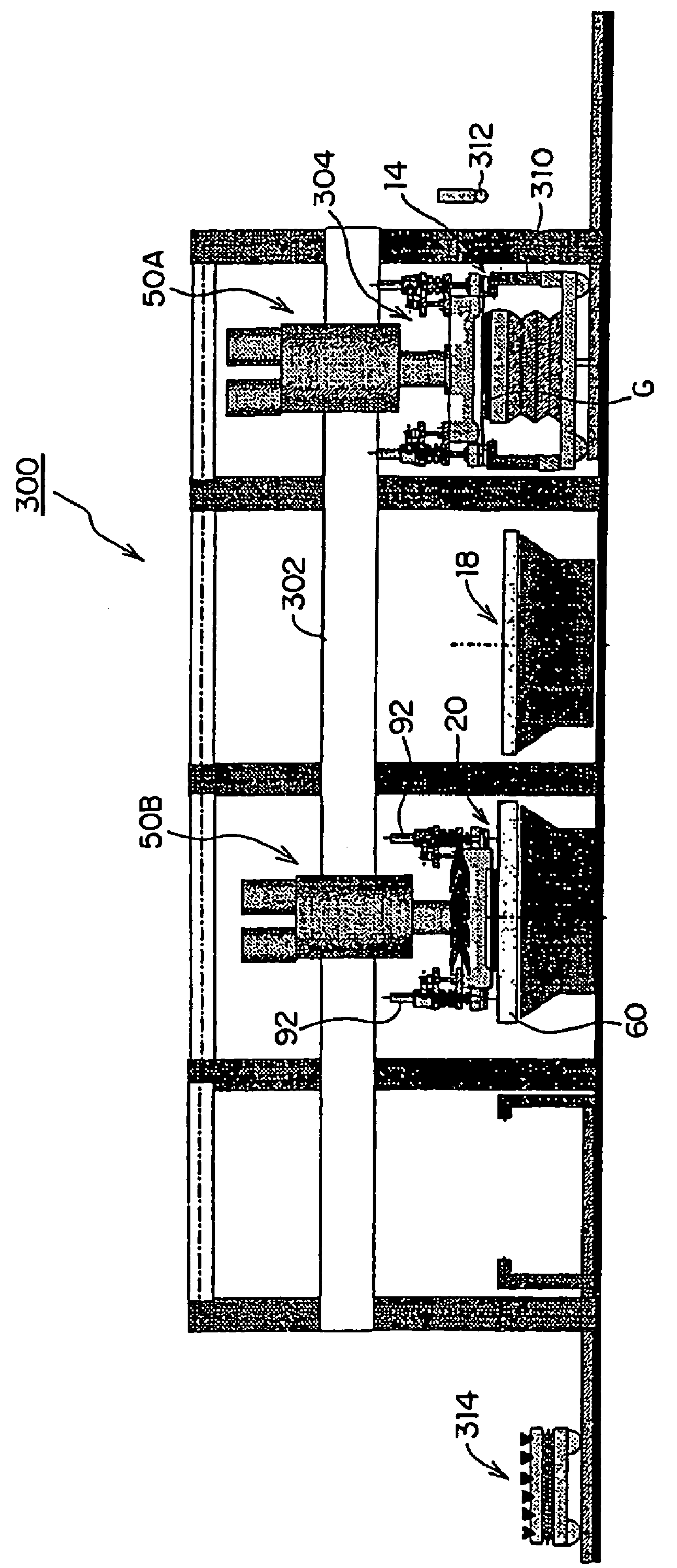
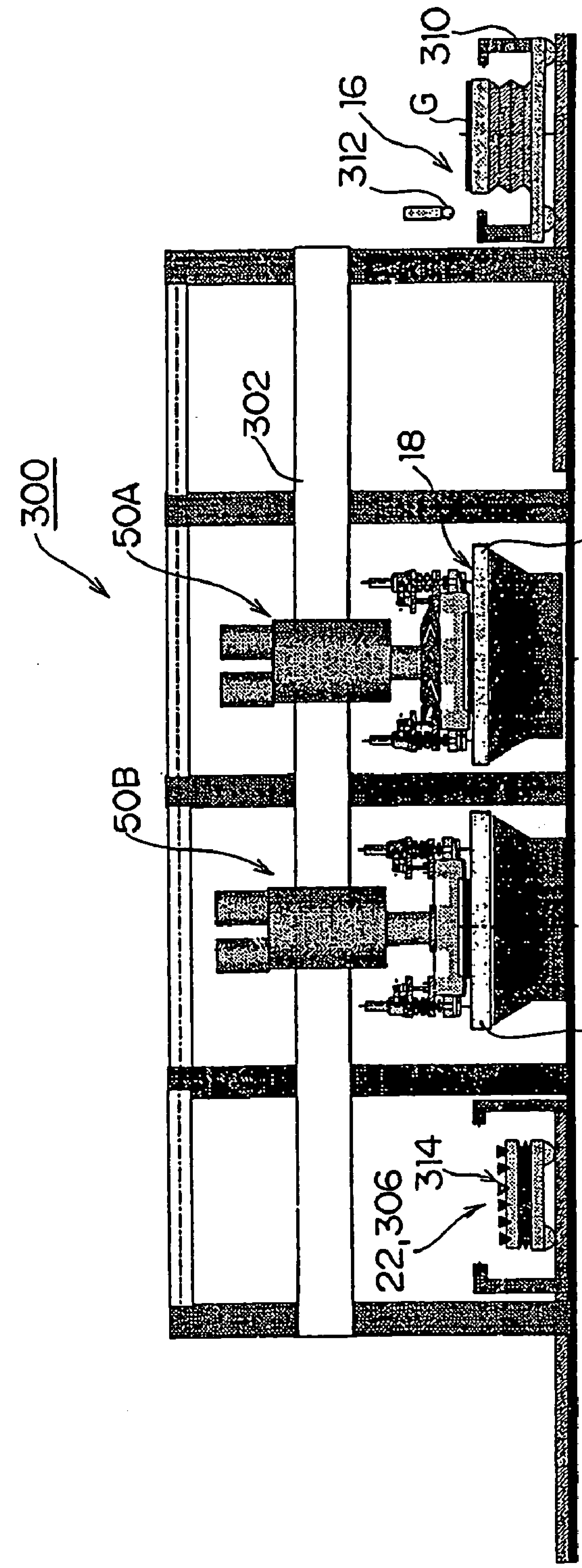


Fig. 28



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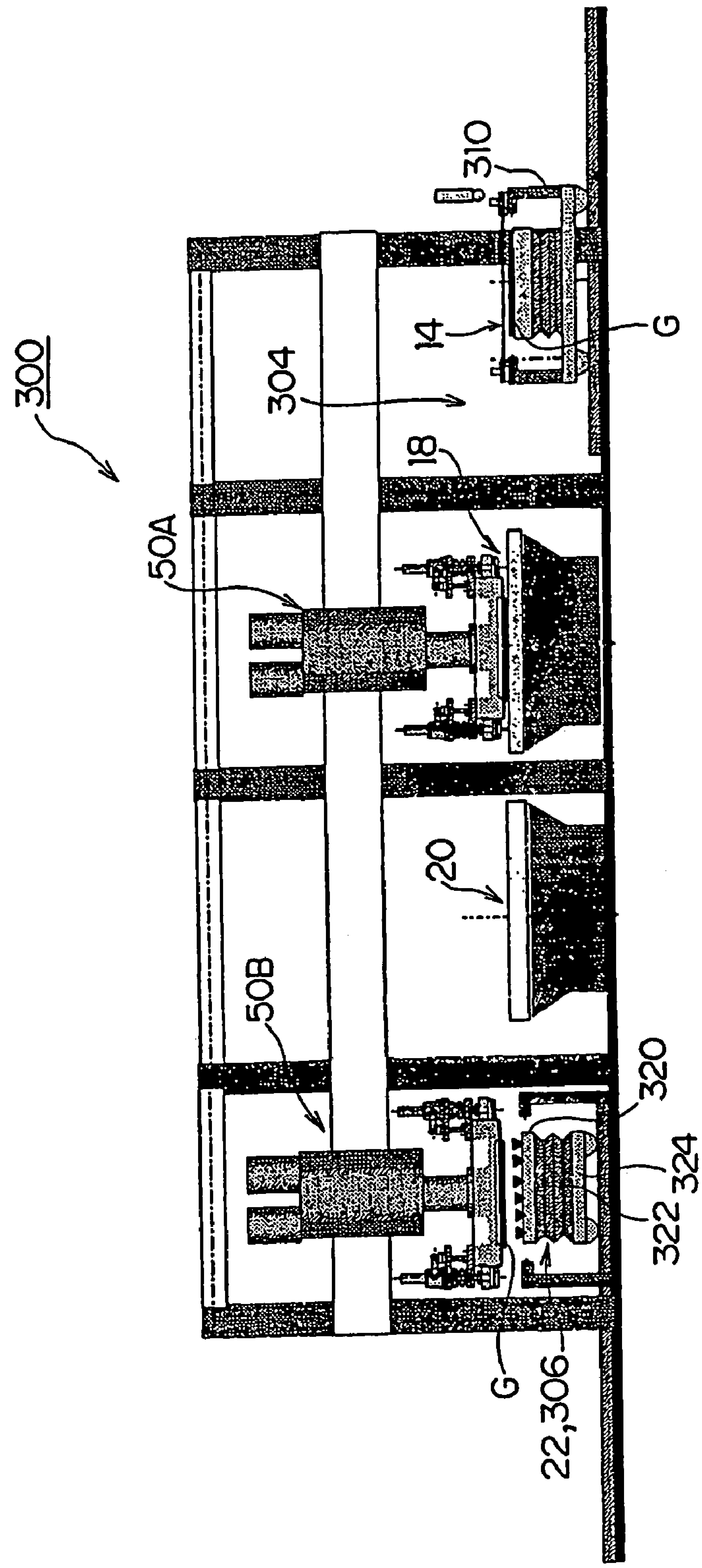

Fig. 30

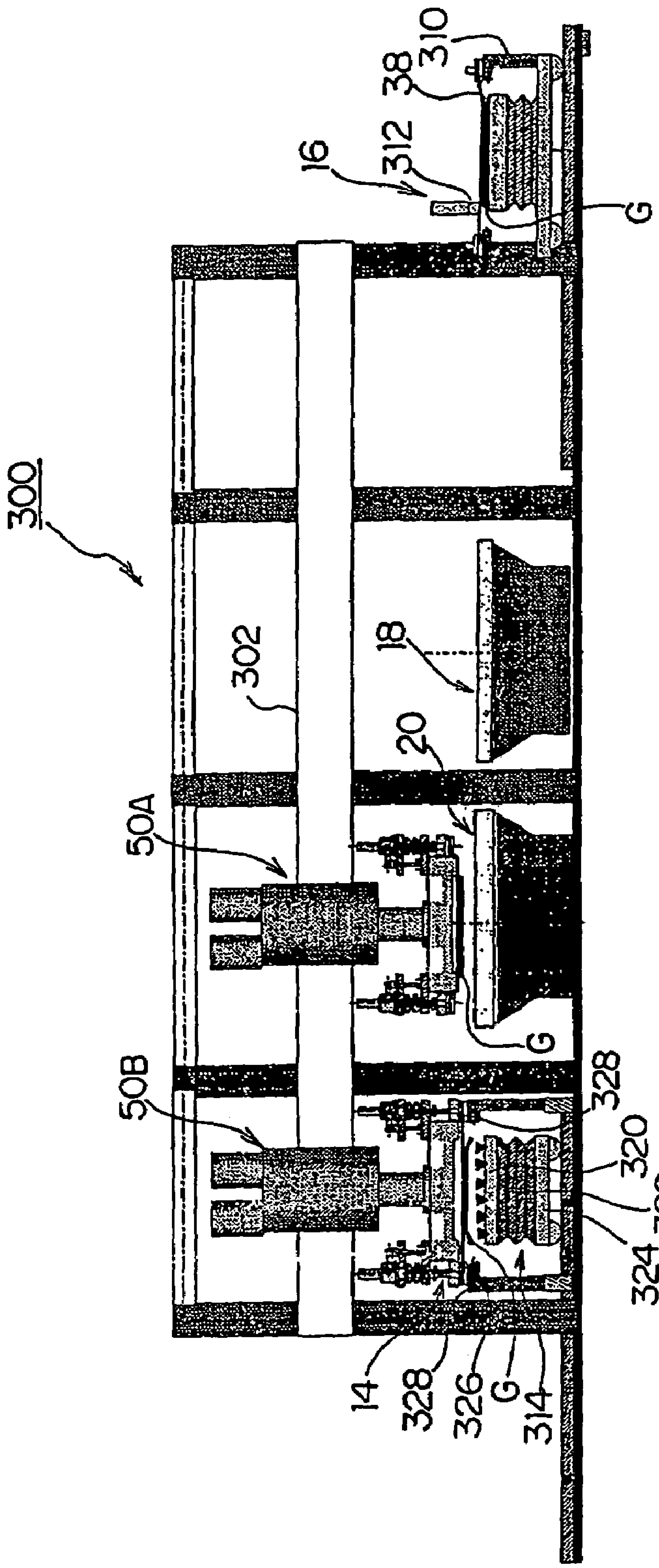
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Fig. 31

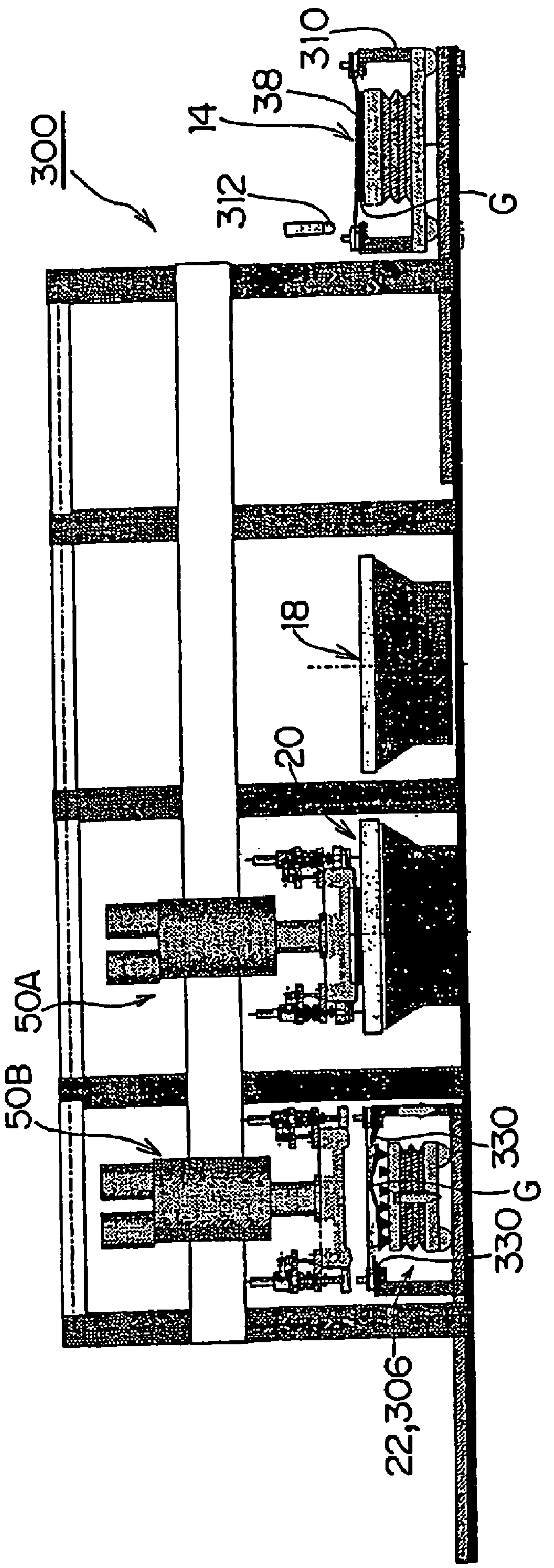


Fig. 32

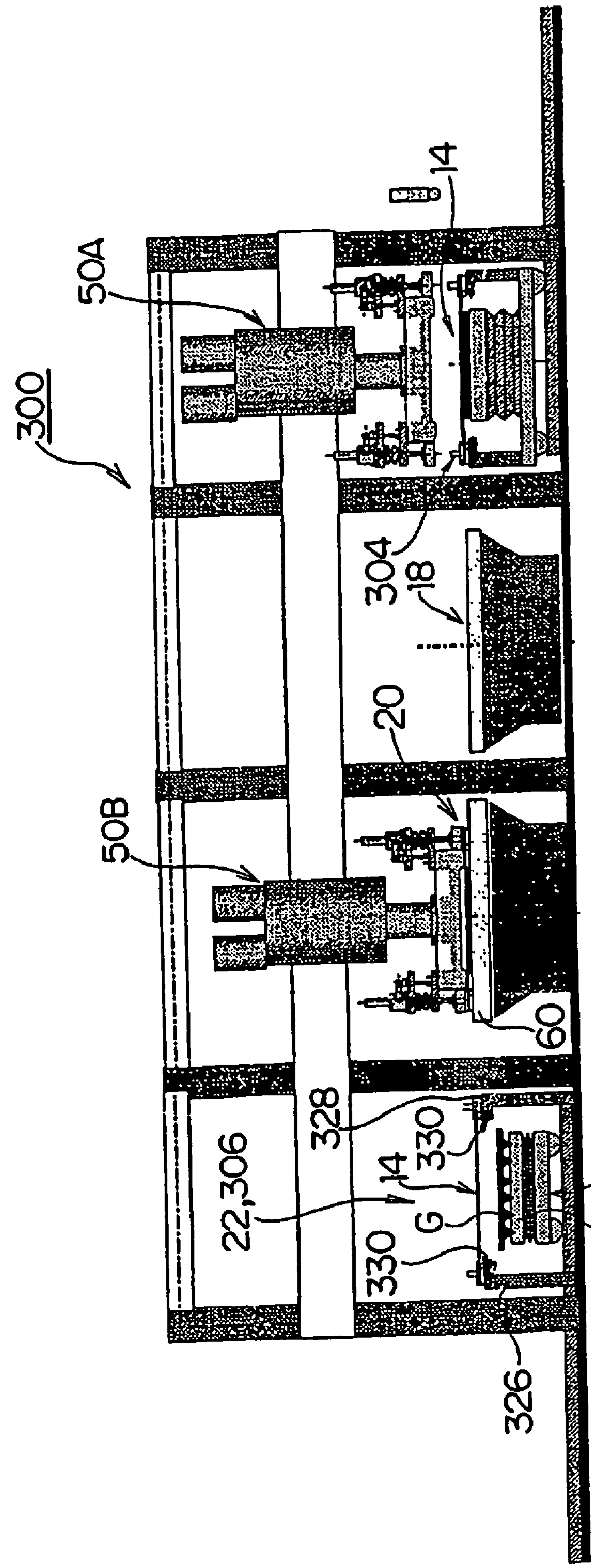


Fig. 33

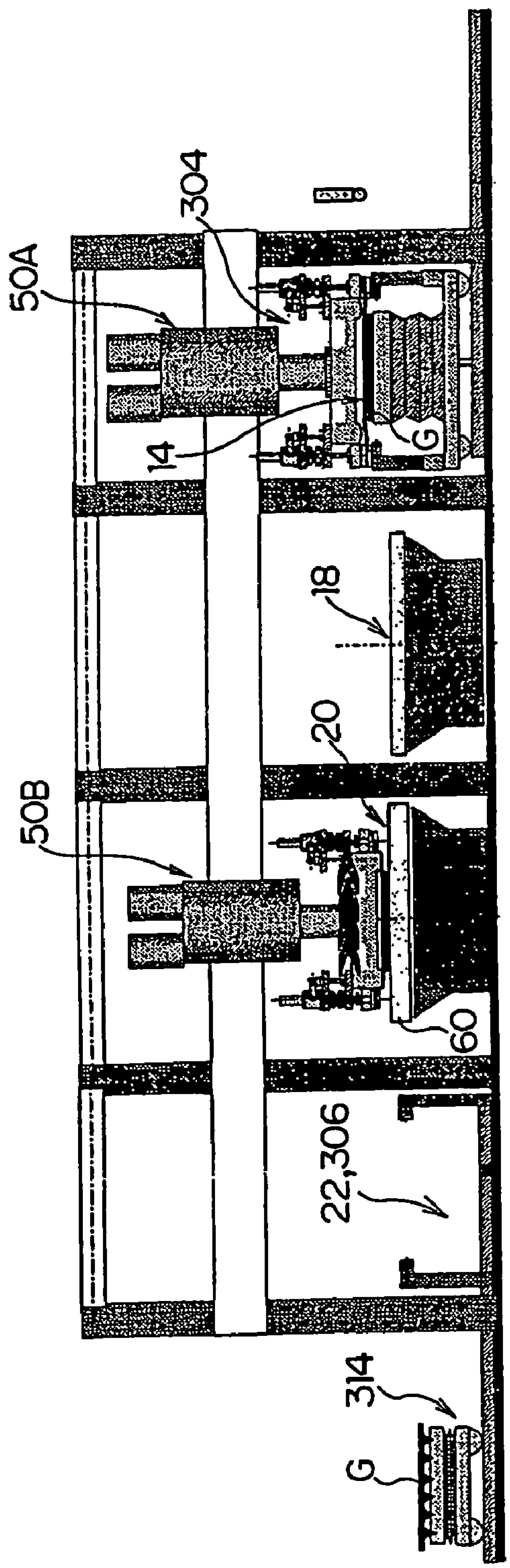


Fig. 34

Fig. 35

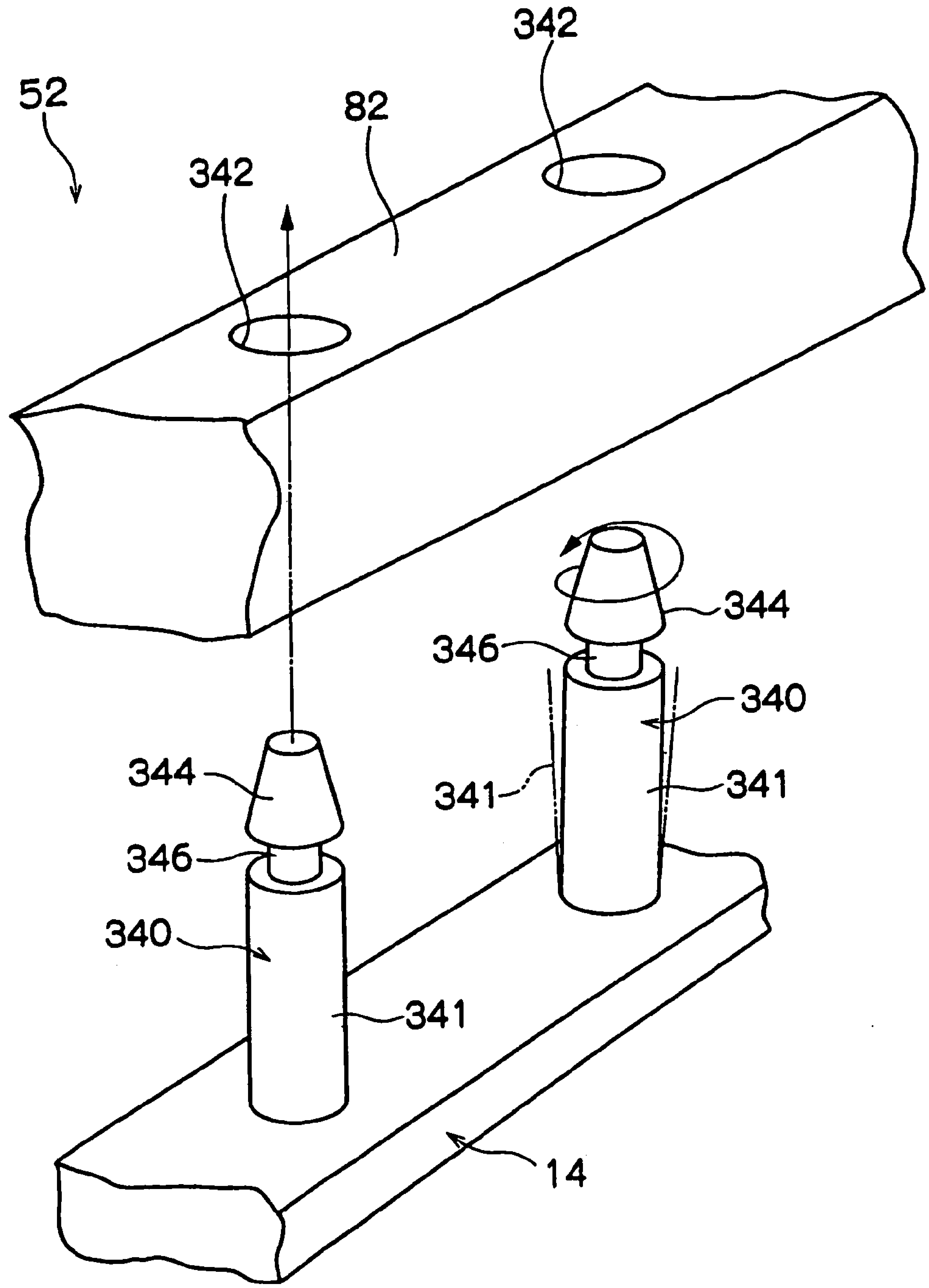


Fig. 36(A)

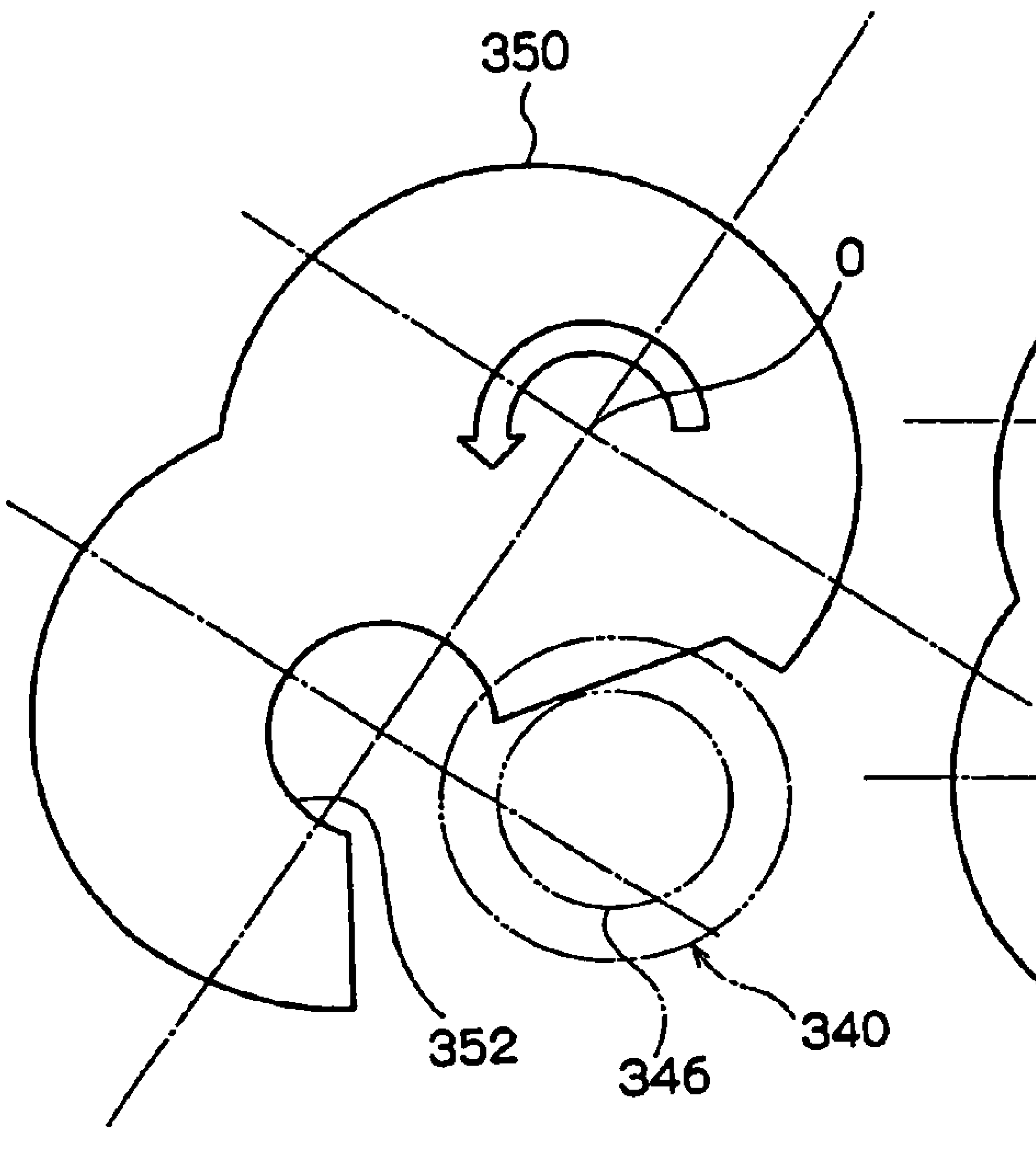
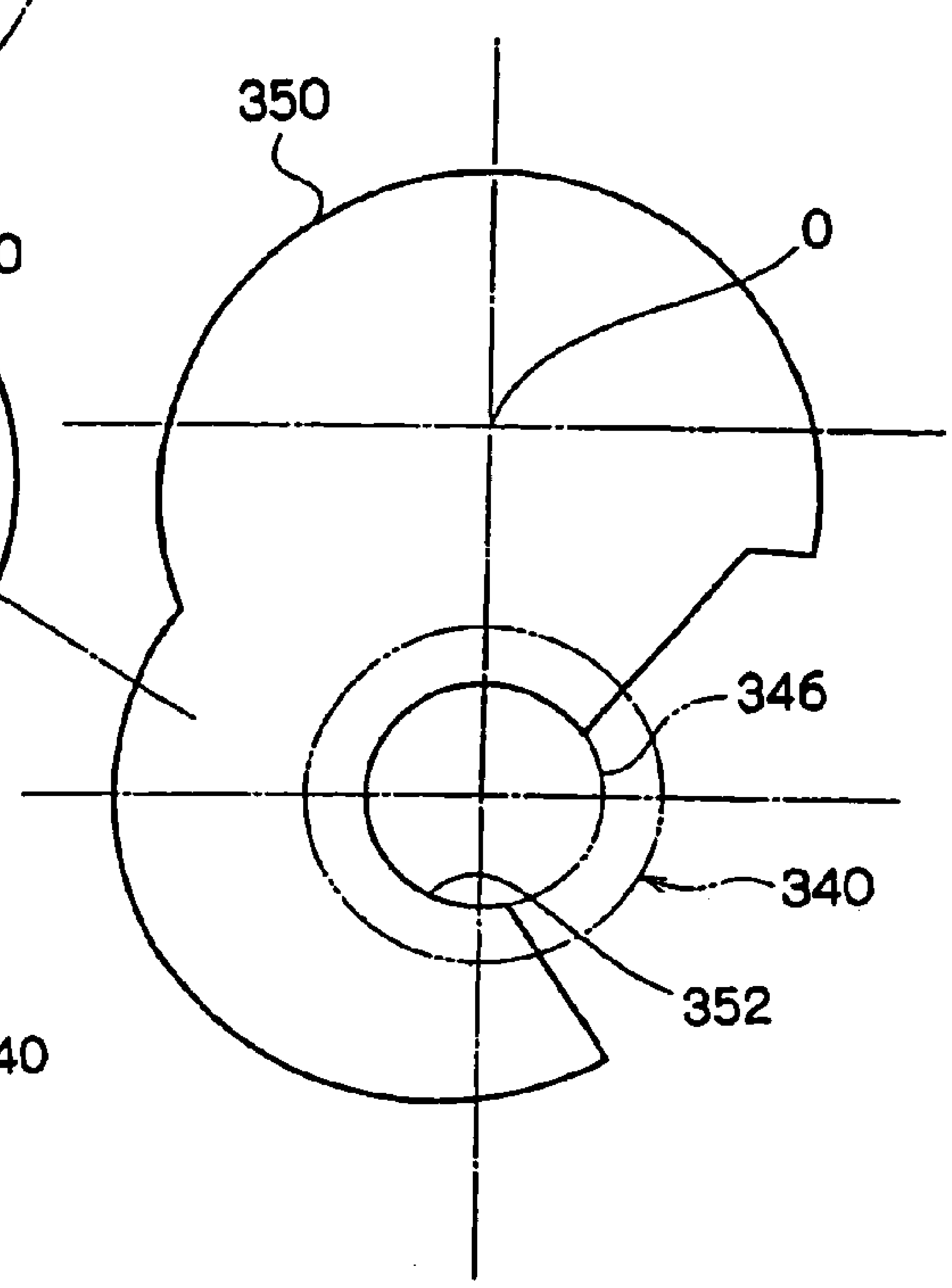


Fig. 36(B)



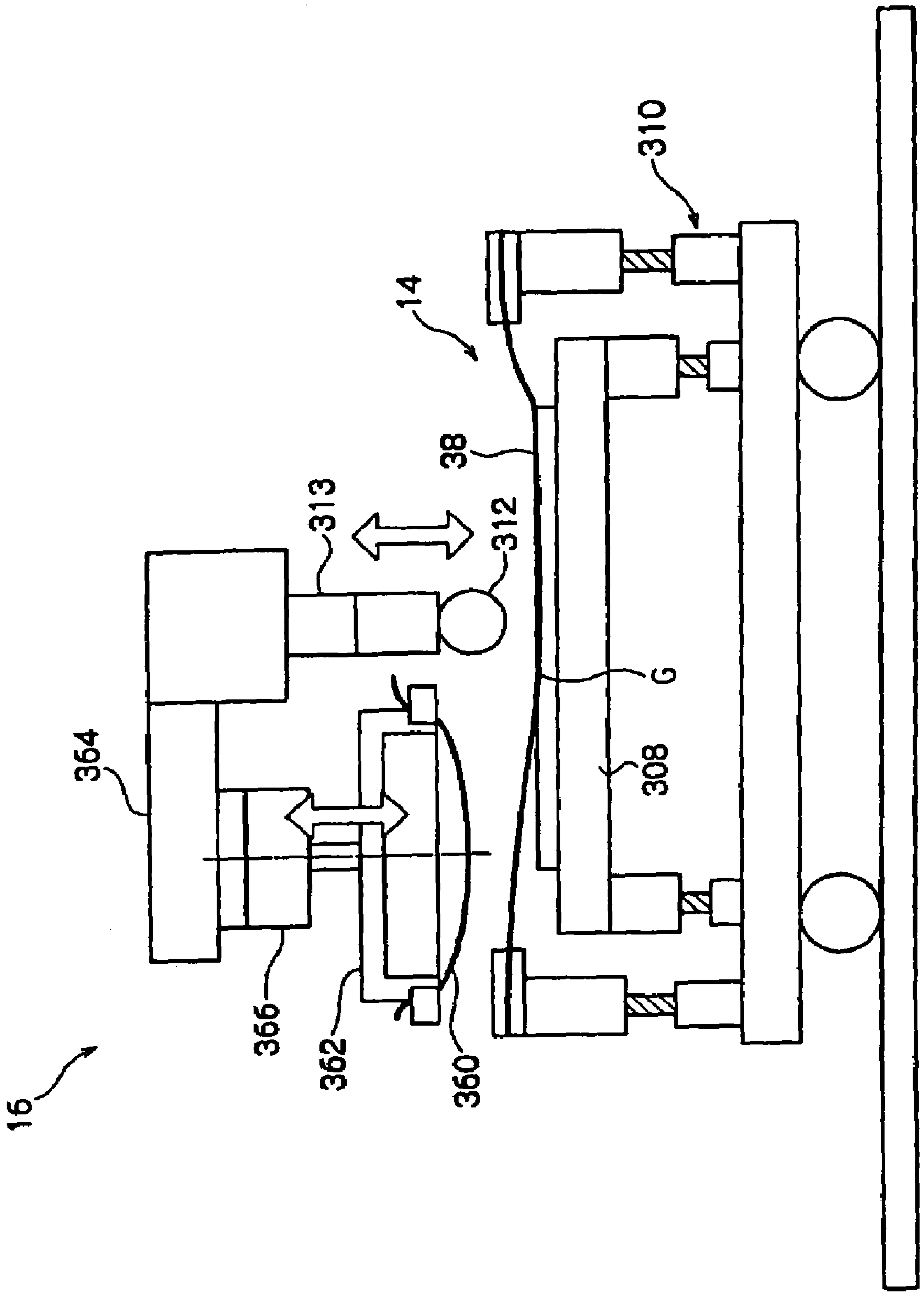


Fig. 37

METHOD AND APPARATUS FOR POLISHING A SUBSTRATE

This is a Divisional application of Ser. No. 11/045,089 filed Jan. 31, 2005 now U.S. Pat. No. 7,115,022 which is a CON of PCT/JP03/09745 filed Jul. 31, 2003 and claims priority to Japan 2002-223001 filed Jul. 31, 2002, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a method and device for polishing a substrate. In particular, it relates to a method and device for polishing a glass substrate to manufacture a glass substrate for liquid crystal display.

BACKGROUND ART

A glass substrate used for liquid crystal display has minute recesses and projections or undulation in its surfaces, which causes a deformed picture image. Accordingly, such minute recesses and projections or undulation should be eliminated with a polishing device. As such polishing device, there has generally been known a polishing device in which a glass substrate held by a carrier is pressed to a polishing cloth disposed on a polishing surface-plate while the polishing surface-plate and the carrier are rotated relative to each other to polish the glass substrate.

Further, in the polishing device disclosed in JP-A-9-141550, a flexible film is disposed at a lower portion of the carrier and pressurized air is supplied between the flexible film and the carrier so that the pressure of the pressurized air urges the substrate attached to the flexible film to the polishing cloth for polishing. According to this polishing device, there is an advantage that the pressurized air in the space between the flexible film and the carrier applies pressure uniformly to each part of the substrate whereby the substrate can be polished flat, and minute recesses and projections in the substrate surface can be eliminated.

However, in the conventional polishing device, there is no proposal about a discharging means for discharging a glass substrate which has been polished and removed from the carrier, from a polishing stage. Particularly, in a case of a large-sized glass substrate, the length of a side of which is, for example, beyond 1,000 mm, the removal and handling of it in the polishing stage and the discharge of it from the polishing stage were very difficult and took a long time to thereby reduce productivity.

With the increase of the size of a liquid crystal display screen in recent years, a polishing device for a large-sized glass substrate, which can solve the above-mentioned problem of discharging a glass substrate after being polished and can improve productivity, has been expected.

The present invention has been made in consideration of the above-mentioned circumstances, and it is an object of the present invention to provide a method and device for polishing a glass substrate suitable for polishing a large-sized glass substrate.

DISCLOSURE OF THE INVENTION

In order to achieve the above-mentioned object, the method for polishing a substrate of the present invention is characterized by comprising a process for attaching a substrate to a frame with a film on which the film capable of attaching the substrate is stretched and installing the frame on a carrier, or a process for installing a frame on which a film capable of attaching a substrate is stretched on a carrier and attaching the substrate to the frame; a process for bringing the carrier holding the frame and a polishing surface-plate closer relative to each other and polishing a surface to be polished of the substrate attached to the film by pressing the substrate to the polishing surface-plate; and a process for removing the frame from the carrier after the completion of the polishing of the substrate and removing the substrate from the frame, or a process for removing the substrate from the frame after the completion of the polishing of the substrate and removing the frame from the carrier.

Preferably, the present invention is characterized by comprising a process for attaching a glass substrate to a frame on which a film capable of attaching a glass substrate is stretched, a process for installing on a carrier the frame to which the glass substrate is attached, a process for bringing the carrier with the frame and a polishing surface-plate closer relative to each other and polishing a surface to be polished of the glass substrate attached to the film by pressing the glass substrate to the polishing surface-plate, a process for removing the frame from the carrier after the completion of the polishing of the glass substrate, and a process for removing the polished glass substrate from the frame.

Further, in order to achieve the above-mentioned object, the polishing device of the present invention is characterized by comprising a substrate attaching stage for attaching a substrate to a frame on which a film capable of attaching the substrate is stretched;

a frame installing stage for installing the frame on a carrier; a polishing stage for polishing the substrate by bringing the carrier and a polishing surface-plate closer relative to each other after the installation of the frame on the carrier and pressing a surface to be polished of the substrate attached to the frame, to the polishing surface-plate; a substrate removing stage for removing the frame from the carrier, and a substrate removing stage for removing the polished substrate from the frame.

Preferably, the polishing device is characterized by comprising a glass substrate attaching stage for attaching a glass substrate to a frame on which a film capable of attaching the glass substrate is stretched, a polishing stage for polishing a surface to be polished of the glass substrate attached to the film by bringing the carrier and a polishing surface-plate closer relative to each other after the installation of the frame on the carrier and pressing the substrate to the polishing surface-plate, and a glass substrate removing stage for conveying the frame removed from the carrier after the completion of the polishing of the glass substrate and removing the polished glass substrate from the frame.

Further, according to the present invention, an unpolished glass substrate is attached to the film of a frame in the glass substrate attaching stage. Then, the frame to which the glass substrate is attached is installed on the carrier in the frame installing stage. In this case, the frame may be installed on the carrier in the frame installing stage and then, the unpolished glass substrate may be attached to the film of the frame in the glass substrate attaching stage.

Then, in the polishing stage, the carrier on which the frame is installed and the polishing surface-plate are brought closer relative to each other and the polishing is performed by pressing the surface to be polished of the glass substrate attached to the film to the polishing surface-plate.

Then, after the completion of polishing the glass substrate, the frame is conveyed from the polishing stage to the frame removing stage in which the frame is removed from the carrier, and thereafter, the polished glass substrate is removed from the frame in the glass substrate removing stage. In this case, the frame may be removed from the carrier in the frame removing stage after the polished glass substrate is removed from the frame in the glass substrate removing stage.

Thus, in the present invention, the glass substrate is attached to the frame capable of being attached to and detached from the carrier, and after the completion of the polishing, the polished glass substrate is removed from the frame in the glass substrate removing stage remote from the polishing stage, instead of removing the glass substrate from the frame in the polishing stage. With this measures, the present invention can solve the problem inherent in conveying a large-sized glass substrate and can improve productivity.

Further, in a preferred embodiment of the present invention, the frame is washed in the washing stage after the glass substrate is removed, and this frame can be used repeatedly for the attachment of another glass substrate. Accordingly, the number of frames to be prepared can be minimized, and accordingly, the present invention can contribute to resource saving.

According to another preferred embodiment of the present invention, pressurized fluid is supplied between the carrier and the film of the frame from a supply means for supplying pressurized fluid for polishing to create a pressure of pressurized fluid therebetween whereby the glass substrate is pressed for polishing to the polishing surface-plate. Since the pressure of pressurized fluid is applied uniformly to each part of the glass substrate, the glass substrate can be polished flat. Incidentally, the glass substrate is not influenced by the surface profile of the polishing surface-plate, i.e., even though the polishing surface-plate has some undulation in its surface. Therefore, the undulation is not transferred to the glass substrate. Accordingly, a strict requirement of precision to the polishing surface-plate is unnecessary, and cost for the polishing surface-plate can be reduced.

The film used preferably in the present invention has a three-layer structure comprising an air-tightness retention layer having a outer circumferential portion adhered tightly to the carrier to retain air-tightness between the film and the carrier, a strength retention layer holding the air-tightness retention layer and having a predetermined tensile stress durable to a tension for stretching the film, and a smooth layer to which the glass substrate is attached. Accordingly, the glass substrate can be held stably by the film whereby the glass substrate can be polished with accuracy.

In another embodiment of the present invention, the strength retention layer of the film is made of aramid fibers, a mesh of stainless steel, a mesh of steel, carbon fibers, glass fibers, nylon fibers or a material having the same tensile strength as these materials. Accordingly, the strength of the film can be assured when the glass substrate is pressed to the polishing surface-plate with a pressing force suitable for the polishing.

Further, according to another embodiment of the present invention, fluid is supplied from a supply means for supplying fluid for separating to the boundary between the film of the frame and an edge portion of the substrate in the substrate removing stage, whereby the substrate can be separated from the frame due to a separating function produced by the supply of the fluid. When the substrate is to be separated from the frame, it is possible to separate the substrate by its own weight. However, it takes much time. According to the present invention, the separating function is produced forcibly by supplying the fluid whereby the substrate can be separated from the frame in a shorter time to thereby increase productivity.

According to another embodiment of the present invention, a substrate is placed on a table in the substrate attaching stage, and then, the film of a frame is placed on the substrate on the table, and then, a press roller is pressed to the film placed on the substrate while the table and the press roller are moved relatively along the surface of the film by a moving means, whereby the substrate is attached to the film by the press roller.

The present invention can effectively be applied to a method and device for polishing a substrate, particularly, for polishing a substrate having a large surface area. In the production of a substrate having a small surface area, the substrate can be attached to a film without causing air bubbles between the substrate and the film by pressing simply the substrate to the film. The presence of air bubbles reduces the attaching strength. In order to obtain assured attaching, the amount of air bubbles should be minimized as possible. If the substrate having a large surface area is simply pressed to the film, a large amount of air bubbles exists because the degree of flatness of each of the film and the substrate is high. According to the present invention, the substrate and the film can be attached by pressing them with the press roller to discharge forcibly air bubbles existing between the film and the substrate. With this, the substrate of large surface area can certainly and firmly be attached to the film.

According to another preferred embodiment of the present invention, the frame is connected detachably to the carrier by means of a plurality of pins wherein a predetermined number of pins among the plurality of pins are fitted to be swung to the frame and the remaining pins are fixed thereto so as to be used for determining the position to the carrier.

The above-mentioned preferred embodiment of the present invention is also effective to the method and device for polishing a substrate, particularly, a substrate of large surface area. In the case that the frame and the carrier are connected, to determine mutual positions, by fitting a plurality of pins mounted on the frame to a plurality of openings formed in the carrier and that the frame is a small-sized frame, all the pins can be fitted to the openings even though these pins are mounted fixedly on the frame because accuracy in mounting the pins can easily be obtained. On the other hand, in the case of a large-sized frame to which a substrate of large surface area is to be attached, it is difficult to mount pins with accuracy. Accordingly, if all the pins are mounted fixedly, it is difficult to fit all the pins into the openings. On the other hand, if all the pins are mounted on the frame so that each pin can be swung with respect to its axis, an error of mounting can be absorbed by their swinging movement. Accordingly, all the pins can be fitted to the openings. However, if all the pins are mounted so as to be swung, it is impossible to determine the mutual positions because the frame can not be stable with respect to the carrier. Further, the pins have to resist against the shearing force of the polishing surface-plate at the time of the polishing. Accordingly, there is a possibility that they can not withstand against the shearing force.

According to the present invention, a predetermined number of pins among the plurality of pins are mounted on the frame so that they can be swung with respect to their axes, to absorb error in mounting each pin. The remaining pins are mounted fixedly on the frame to resist the shearing force to each of these pins applied from the polishing surface-plate. Accordingly, the large-sized frame can stably be connected to the carrier with accurate positional relation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view showing the entire structure of the polishing device according to a first embodiment.

FIG. **2** is a side view showing polishing heads and polishing stages as an embodiment.

FIG. **3** is a perspective view of a polishing head disassembled.

FIG. **4** is diagram showing the three-layer structure of a film to be attached to a frame.

FIG. **5** is an enlarged cross-sectional view of an important portion showing an attaching/detaching structure for the frame to a slide-contact ring.

FIG. **6** shows enlarged cross-sectional views of important portions showing other attaching/detaching structures for the frames to slide-contact rings.

FIG. **7** shows enlarged views of important portions showing other attaching/detaching structures for the frames to slide-contact rings.

FIG. **8** is a schematic structural view of a conveying device for a glass substrate.

FIG. **9** is a diagram showing a glass substrate attaching process as well as a frame and a carrier.

FIG. **10** is a diagram showing a separating process for separating a glass substrate from a frame.

FIG. **11** is a front view of the polishing device according to a second embodiment.

FIG. **12** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **13** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **14** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **15** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **16** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **17** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **18** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **19** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **20** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **21** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **22** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **23** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **24** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **25** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **26** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **27** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **28** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **29** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **30** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **31** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **32** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **33** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **34** is a diagram showing an operation of the polishing device shown in FIG. **11**.

FIG. **35** is a perspective view of an important portion showing a position determining structure for a frame to a carrier.

FIG. **36** is a plan view of a hook to be engaged with a pin in the position determining structure shown in FIG. **35**.

FIG. **37** is a side view showing the structure of a press roller with a balloon.

EXPLANATION OF NUMERALS

10, **300**: polishing device, **12**: conveyer, **14**: frame, **16**: stage (glass substrate attaching stage), **18**: first polishing stage, **20**: second polishing stage, **22**: stage (glass substrate removing stage), **24**: glass substrate discharging conveyer, **26**: frame washing stage, **28**: frame drying stage, **30**: frame returning conveyer, **32**: robot, **33**: arm, **34**: suction pad, **36**: conveyer, **38**: film, **40**: upper frame, **42**: lower frame, **44**: air-tightness retention layer, **46**: strength retention layer, **48**: smooth layer, **50**, **50**A, **50**B: polishing head, **51**: casing unit, **52**: carrier, **53**: lower peripheral ring, **54**: air chamber, **56**: spindle, **58**: polishing pad, **60**: polishing pad, **62**: polishing surface-plate, **64**: rotary shaft, **66**: polishing surface-plate, **68**: rotary shaft, **70**: rectilinear guide, **72**: guide rail, **74**: maintenance stage, **76**: maintenance stage, **78**: suspender ring, **80**: penetration hole, **82**: slide-contact ring, **84**: slide-contact ring suspender, **86**: upper spring, **88**: spring for lifting, **90**: penetration hole, **92**: screw jack, **94**: stopper pin, **96**: line shaft, **98**: jet orifice, **100**: air chamber, **102**: air supply channel, **104**: valve, **106**: air pump, **108**: pin, **110**: head portion, **112**: hook, **114**: pin, **116**: recess, **118**: stopper plate, **120**: air passage, **122**: clamper, **124**: clamping plate, **126**: pole, **128**: penetration hole, **130**: penetration hole, **132**: pin supporting member, **134**: penetration hole, **136**: stopper pin, **138**: conveyer, **140**: robot, **142**: arm, **144**: suction head, **146**: conveyer, **150**, **152**, **154**: conveying device, **160**: guide rail, **162**: holder, **164**: small-sized robot, **166**: arm, **168**: guide block, **170**: guide rail, **200**: table, **202**: jack, **204**: table, **206**: air nozzle, **208**: jack, **302**: rail, **304**: frame installing stage, **306**: frame removing stage, **308**: table, **310**: plate attaching shuttle, **312**: press roller, **314**: plate separating shuttle, **316**: elevating device, **320**: table, **322**: elevating device, **324**: shuttle main body, **326**: conveying table, **330**: air nozzle (means for supplying fluid for separation), **340**: pin, **342**: opening, **344**: tip portion, **346**: thin portion, **350**: hook, **352**: fitting portion, **360**: film pressing balloon, **362**: head, **364**: supporter, **366**: cylinder unit

BEST MODE FOR CARRYING OUT THE INVENTION

In the following, preferred embodiments of the method and device for polishing a glass substrate of the present invention will be described with reference to the attached drawings.

In a first embodiment, a polishing device **10** is shown in FIG. **1**, which is to polish a single surface of a large-sized glass substrate G (having, for example, a side exceeding 1,000 mm and a thickness of from 0.3 mm to 1.1 mm) to have a flatness necessary for a glass substrate used for liquid crystal display.

This polishing device **10** comprises mainly a conveyer **12** for conveying an unpolished glass substrate G, a stage **16** for attaching the glass substrate G to a frame **14** (glass substrate attaching stage), a first polishing stage **18**, a second polishing stage **20**, a stage **22** for removing the polished glass substrate G from the frame **14** (glass substrate removing stage), a glass substrate discharging conveyer **24**, a frame washing stage **26**, a frame drying stage **28** and a frame returning conveyer **30**.

Further, the polishing device **10** is provided with a conveying device **150** for conveying the frame **14** from the stage **16** to the first polishing stage **18**, a conveying device **152** for conveying the frame **14** from the first polishing stage **18** to the second polishing stage **20** and a conveying device **154** for conveying the frame **14** from the second polishing stage **20** to the stage **22**. The number of polishing stages may be only one or more than two, which depends on intended use. In consideration of efficiency and cost, it is preferred to install two stages of a rough polishing stage and a fine polishing stage. However, if the case requires, the fine polishing stage may be added to obtain high quality.

An unpolished glass substrate G conveyed by the conveyer **12** is sucked and held by a suction pad **34** provided on the arm **33** of a robot **32**, and it is transferred from the conveyer **12** to a conveyer **36** by a turning motion of the arm **33**. Then, it is conveyed by the conveyer **36** to the stage **16**. In the stage **16**, the glass substrate G is attached to a frame **14**. Description will be made as to the method of attaching. In the stage **16**, the frame **14** is held on an elevating device (not shown) as a glass substrate attaching means. When the glass substrate G is positioned below the frame **14**, the frame **14** is moved downward by means of the elevating device so that a film (see FIG. **3**) stretched on the frame **14** is pressed to the glass substrate G. By this pressing force, the glass substrate G is attached to the film **38**. Then, the frame **14** is held on the conveying device **150** in FIG. **1** and is conveyed to the first polishing stage **18** shown in FIG. **2**, at which the frame is installed on a carrier **52**. The glass substrate attaching means is not limited to the elevating device but any suitable means may be used as long as the glass substrate G can be attached to the frame **14**. Here, the frame **14** described herein means the entirety including the stretched film **38**.

As shown in FIG. **3**, the frame **14** is constituted by stretching the film **38** which is adhesive to the glass substrate G between an upper frame **40** and a lower frame **42** and by fastening the upper frame **40** and the lower frame **42** by means of bolts (not shown).

The frame **14** and the film **38** are not limited to have a circular shape but they may have a rectangular shape.

The film **38** has a three-layer structure comprising an air-tightness retention layer **44**, a strength retention layer **46** and a smooth layer **48** as shown in FIG. **4**. The air-tightness retention layer **44** is a sheet material having its outer peripheral portion being adhered tightly to a lower peripheral ring **53** in the carrier **52** so as to maintain air-tightness of an air chamber **54** formed between the layer and the carrier **52**. As the material for the sheet material, rubbers, silicons, fluorine resin, vinyls such as polyvinyl chloride (PVC), nylons and urethane may be mentioned. However, polyvinyl chloride or urethane is preferred from the standpoint of manufacturing. In particular, such one made of urethane is preferred. The strength retention layer **46** in FIG. **4** is a sheet material which can hold the air-tightness retention layer **44** and has a predetermined tensile strength durable to a tensile force for stretching the film **38**.

Here, the tensile strength required for the strength retention layer **46** is calculated on the basis of a frictional force acting on the glass substrate G at the time of the polishing. When the glass substrate G have a size L, the frictional force acting on the glass substrate G at the time of the polishing is presented by "a friction coefficient of a polishing tool to the glass substrate G at the time of the polishing"×"a surface area per a unit width (cm) of the glass substrate G"×"pressure of polishing"$=\mu\times Lm\times 10^{-2}\times kPa$.

For instance, when $\mu=0.3$, L=1 m and p=3 kPa, $0.3\times 10^{-2}\times 3\times 10^{3}=9$N.

Accordingly, the tensile strength required for the strength retention layer **46** needs to have a tensile force strong enough to the frictional force. Accordingly, in terms of a strip-like region having a unit width (1 cm) in the strength retention layer **46**, a tensile strength of more than 9 N is required.

Assuming that a glass substrate having a large surface area is subjected to a high pressure of polishing, for example, when $\mu=0.5$, L=1.8 m and p=20 kPa, the tensile strength required for the strength retention layer **46** in this embodiment needs to have a tensile strength of at least 180 N in terms of a strip-like region having a unit width (1 cm) in the strength retention layer **46**.

Rubber or resins are generally considered as the material for the strength retention layer **46**. However, the strength retention layer is made of a material such as alamide fibers, a mesh of stainless steel, a mesh of steel, carbon fibers, glass fibers, nylon fibers, a metallic sheet, a resin sheet or the like so as not to cause the deformation in practical use wherein the tensile strength is at least 9 N/cm even in a case of L=100 cm and a pressure of pressing of about 3 kPa, particularly, the tensile strength is at least 180 N/cm in a case of L=180 cm from practical use and in addition, in consideration of an impact load. The particularly preferred material is alamide fibers because they have very small elongation to the tensile force.

Since the glass substrate G is rotated when it is polished actually, the maximum tensile force applied to the strength retention layer **46** is calculated based on the length of a diagonal line of the glass substrate G. In this embodiment, the calculation was made based on the length of a longer side of the glass substrate G in order to simplify the calculation.

The smooth layer **48** is constituted by bonding a glass-holding sheet used commonly to attach the glass substrate G. However, if the surface irregularity of the smooth layer **48** is large, there causes the problem that the surface irregularity is transferred to the glass substrate G at the time of polishing. Accordingly, the smooth layer **48** has to be flat and smooth. However, when resin or a rubber layer is applied by using a coating technique such as gluing, a local surface irregularity may take place. If this can not be avoided, a flat sheet can be formed by bonding a thin sheet according to a laminating process. The thin sheet may be of, for example, urethane, PVC, PET, PP as long as smoothness can be maintained. Urethane or PVC is preferred because a common laminating process can be used. In particular, a thin sheet of urethane is preferred. Specifically, the flatness of the smooth layer **48** be at most 0.1 mm per 100 mm^2 in terms of surface irregularity. In order to obtain a sufficient flatness, a plurality of smooth layers **48** may be overlaid. Further, the sheet thickness of the film **38** is preferably from about 0.1 mm to 5 mm in order to provide flexibility. Further, the thin sheet may be a porous sheet having a sucking function to the glass substrate G. In this case, the sucking function can be improved by forming previously a water film on the surface of the glass substrate G or the surface of the sheet.

The polishing pad of the polishing stage is generally subjected previously to truing to remove a minute undulation in the surface layer. For this purpose, a grinding unit for truing is generally installed in the polishing device. It is naturally for the grinding unit for truing to have a high precision because it provides the standard for the polished surface.

In this embodiment, the truing is carried out by attaching a commercially available sheet containing polishing powder to the film **38** of the frame **14** installed on the carrier **52**. Namely, in the same manner as the polishing of the glass substrate G, the commercially available sheet attached to the film **38** of the frame **14** is pressed to the polishing pad of the polishing stage under the application of a uniform pressure by pressurized fluid, which is described later, while the sheet and the pad are moved relatively, whereby the truing of the polishing pad is carried out. This provides the advantage of eliminating a highly precise grinding unit. Incidentally, since the frame **14** attached with the polishing sheet instead of the glass substrate G can be put into the production line with a minimum interference to the production cycle, the interference to the production due to the truing can be controlled to the minimum.

Next, the polishing heads **50** shown in FIG. **2** will be described. The polishing head **50** of the first polishing stage **18** had the same structure as the polishing head **50** of the second polishing stage **20**. Accordingly, the same reference numeral is used for these polishing heads.

Each polishing head **50** comprises a casing unit **51** including a motor, the output shaft of the motor being connected to a spindle **56** extending in a vertical direction. A carrier **52** is connected to the spindle **56**. The casing unit **51** is connected to a slider **158** by a elevating devices **156**. The elevating devices **156** move each casing unit **51** vertically with respect to each slider **158** whereby carriers **52** are advanced to or retracted from the polishing pad **58** of the first polishing stage **18** and the polishing pad **60** of the second polishing stage **20**, and glass substrates G attached respectively to frames **14** can be pressed to respective polishing pads **58**, **60** with a predetermined pressure of polishing.

The structure of an attaching/detaching means for attaching or detaching the frame **14** to the carrier **52** and the method for attaching or detaching are described later.

The polishing pad **58** is bonded to an upper face of a polishing surface-plate **62**, and a lower portion of the polishing surface-plate **62** is connected with a rotary shaft **64** rotated by a motor not shown. The polishing pad **60** is bonded to an upper face of a polishing surface-plate **66**, and a lower portion of the polishing surface-plate **66** is connected with a rotary shaft **68** rotated by a motor not shown. Here, the motors are not always necessary because there is a case that the polishing pads **58**, **60** need not to be rotated. Instead, the polishing pads **58**, **60** may be swung. In the description of the present invention, “polishing surface-plate” includes a combination of the polishing surface-plate **62** and the polishing pad **58** or a combination of the polishing surface-plate **66** and the polishing pad **60** in this embodiment.

Further, each casing unit **51** is connected to an orbital driving mechanism (not shown) so as to revolve with a predetermined radius of revolution. The orbital driving mechanism may include a planetary gear mechanism in the casing unit **51** so that the output shaft of the planetary gear mechanism is connected to the spindle **56**. Specifications of the first polishing stage **18** and the second polishing stage **20** are described below.

Pressure of polishing: from 2 kPa to 25 kPa

Number of rotation of carrier **52**: from 0 to 25 rpm, radius of orbital revolution: 100 mm (from 50 to 200 mm), number of orbital revolution: from 20 to 150 rpm or from 20 to 200 rpm

Number of rotation of polishing surface-plates **62**, **66**: from 0 to 15 rpm

Polishing slurry: an aqueous solution of cerium oxide is supplied through slurry supplying holes of the polishing surface-plates.

Polishing pad **58**: made of urethane foam with grooves for feeding slurry in its front surface (groove pitch of from 5 to 10 mm, groove width of from 2 to 6 mm, groove depth of from 1 to 5 mm)

Polishing pad **60**: made of suede-like flexible urethane with grooves for feeding slurry in its front surface (groove pitch of from 5 to 10 mm, groove width of from 2 to 6 mm, groove depth of from 1 to 5 mm)

Polishing time: from 1 to 10 min for both the first and the second polishing stages **18**, **20**

Swing motion of carriers **52** to polishing surface-plates **62**, **66**: from 0 to 700 mm in relative movement in a horizontal direction

Thickness of glass substrate G: from 0.3 mm to 3.0 mm

Shape of glass substrate G: rectangular glass sheet having a side exceeding 1,000 mm

Surface without subjecting the polishing of a glass substrate G: held air-tightly with suction pads of polyurethane (glass holding sheets) attached to film **38**

The above-mentioned are the specifications of each of the polishing stages **18**, **20** by which the glass substrates G are polished and minute recesses and projections and undulation in the front surface of the glass substrates G can be removed.

Rectilinear guides **70**, **70** are attached to the slider **158** of the first polishing stage **18**. These rectilinear guides **70**, **70** are respectively fitted to guide rails **72**, **72**. The guide rails **72**, **72** are extended into a maintenance stage **74** in which the spindle **56** and the carrier **52** of the first polishing stage **18** undergo maintenance, as shown in FIG. **1**.

Similarly, rectilinear guides **70**, **70** are attached to the slider **158** of the second polishing stage **20** as shown in FIG. **2**. These rectilinear guides **70**, **70** are respectively fitted to guide rails **160**, **160**. The guide rails **160**, **160** are extended into a maintenance stage **76** in which the spindle **56** and the carrier **52** of the second polishing stage **20** undergo maintenance, as shown in FIG. **1**.

The structure of the carrier **52** will be described. A suspender ring **78** is provided at an upper peripheral portion of the carrier **52** and is fixed thereto by means of bolts (not shown) as shown in FIG. **3**. In a flange portion of the suspender ring **78**, which projects beyond the outer peripheral portion of the carrier **52**, a plurality of penetration holes **80**, **80** . . . are formed with equal intervals on a concentric circle, and slide-contact ring suspenders **84** provided on an upper face of the slide-contact ring **82** are penetrated upward into these penetration holes **80**, **80** . . . as shown in FIG. **5**. Further, each of the slide-contact ring suspenders **84** is inserted into a lifting spring assembly **88** disposed between the suspender ring **78** and a lifting disc spring **86**; is also inserted into a penetration hole **90** of the lifting disc spring **86**, and is connected to a screw jack **92**.

Accordingly, when the screw jack **92** is operated to lift upward the slide-contact ring suspender **84** against the urging force of the suspender ring **88**, the slide-contact ring **82** is lifted with respect to the carrier **52** whereby the frame **14** which is mounted on the slide-contact ring **82** so as to be attached or detached, is lifted so that a predetermined tensile force is exerted to the film **38**.

In order to exert a tensile force to each film **38** automatically, a plurality of frames **14** and films **38** are prepared. In this case, there must consider that there is individual difference among initial tensile forces of films **38** with respect to frames **14**, and there is difference among initial tensile forces of the films **38**, **38** . . . , which are resulted from difference in time of use. Accordingly, it is difficult to exert the same tensile force to every film **38** having an individual difference of tensile force. Further, if an excessive tensile force is applied to a film **38**, the film **38** or a peripheral device may be broken. In order to solve this, the quantity of shrinkage of the lifting spring assembly **88** (the distance between the suspender ring **78** and the lifting disc spring **86**) should be monitored. Namely, the tensile force applied actually to the film **38** is measured by observing not only the quantity of lifting by the screw jack **92** but also the quantity of shrinkage of the lifting spring assembly **88**. The provision of this lifting spring assembly **88** can solve simultaneously problems that a constant tensile force is applied to the film **38** and that an excessive tensile force is not applied to the film **38**. In order to obtain a constant tensile force, it is necessary to measure the quantity of shrinkage of the lifting spring assembly **88**. As one of techniques, the tensile force applied to the film **38** can be observed by calculating a torque of the screw jack **92** based on a current of the motor (not shown) connected to the screw jack via a line shaft **96** to obtain indirectly the lifting force of the screw jack **92** and by controlling the torque. The line shaft **96** is a shaft for transmitting the driving force of the motor to the screw jack **92**. Reference numeral **94** designates a stopper pin which bears the reaction force of the lifting spring assembly **88**, the reaction force generating between the suspender ring **78** and the lifting disc spring **86**.

A plurality of jet orifices **98**, **98** . . . for discharging compressed air into the air chamber **54** are formed in the carrier **52**. These jet orifices **98**, **98** . . . are communicated with an air supply channel **102**, indicated by a broken line in FIG. **2**, via an air chamber **100** formed in an upper face of the carrier **52**. The air supply channel **102** is extended to the outside of each polishing head **50** via a rotary joint (not shown) attached to the polishing head **50** and is connected to an air pump **106** through a valve **104**. Accordingly, when the value **104** is opened, compressed air is supplied from the air pump **106** to the air chamber **54** through the air supply channel **102**, the air chamber **100** and the jet orifices **98**. Thus, the pressure of the compressed air is transmitted to the glass substrate G through the film **38** whereby the glass substrate G is pressed to the polishing pad **58** (**60**) to be polished.

Next, the structure of the attaching/detaching means for attaching the frame **14** to the slide-contact ring **82** or detaching the frame **14** from the slide-contact ring **82** will be described.

As shown in FIG. **3**, a plurality of pins **108**, **108** . . . are projected from an upper frame **40** of the frame **14** with equal intervals on a concentric circle. At the upper edge portion of each of the pins **108**, a large-sized head portion **110** is formed. Each head portion **110** is engaged with each hook **112** fixed to a lower portion of the slide-contact ring **82** whereby the frame **14** is attached to the slide-contact ring **82** as shown in FIG. **5**. The engaging force between the head portion **110** and the hook **112** is increased by the reaction force of the film **38** when the film **38** is stretched by the screw jack **92**. Accordingly, there is no danger of disengaging of the head portion **110** from the hook **112** by the resistance of polishing given by the film **38** at the time of polishing.

The attaching/detaching structure of the frame **14** with respect to the slide-contact ring **82** is not limited to the structure as shown in FIG. **5**, but it may have such a structure that the slide-contact ring **82** is made of a magnetic material, the upper frame **40** of the frame **14** is made of a magnet, and the frame **14** is attracted to the slide-contact ring **82** and held thereto by a magnetic force, for example, as shown in FIG. **6**(A). In this structural example, a pin **114** is provided on the upper frame **40** so as to be inserted in a hole **116** formed in a lower face of the slide-contact ring **82** whereby a horizontal movement of the frame **14** to the slide-contact ring **82** is prevented.

In the structural example shown in FIG. **6**(B), a frame **14** is attracted to a slide-contact ring **82** and is held thereto by a magnetic force in the same manner as FIG. **6**(A). An inner peripheral surface of an upper frame **40** of the frame **14** is made contact with a stopper plate **118** attached to a lower surface of the slide-contact ring **82** whereby a horizontal movement of the frame **14** to the slide-contact ring **82** is prevented.

In the structural example shown in FIG. **6**(C), an air passage **120** is formed in a slide-contact ring **82** and a suction pump is connected to the air passage **120**. The frame **14** is attracted to and held by the slide-contact ring **82** by sucking the upper frame **40** of the frame **14** through the air passage **120**.

In the structural example shown in FIG. **6**(D), a frame **14** is held to a slide-contact ring **82** by a sucking force in the same manner as FIG. **6**(C). A pin **114** of an upper frame **40** is inserted into a recess **116** in the slide-contact ring **82** whereby a horizontal movement of the frame **14** to the slide-contact ring **82** is presented.

In the structural example shown in FIG. **6**(E), a clamper **122** is disposed in an outer peripheral portion of a frame **14** and an outer peripheral portion of a slide-contact ring **82** is clamped between the clamping plate **124** of the clamper **122** and the frame **14** whereby the frame **14** is attached to the slide-contact ring **82**.

In the structure shown in FIGS. **7**(A) and **7**(B), a pole **126** is provided on an upper frame **40** of a frame **14**. This pole **126** is inserted in a penetration hole **128** formed in a slide-contact ring **82**. A penetration hole **130** is formed in an upper end portion of the pole **126**. A pair of pin supporters **132**, **132** each having a penetration hole **134** are fixed on an upper face of the slide-contact ring **82**. A stopper pin **136** is inserted in the penetration hole **130** of the pole and penetration holes **134**, **134** of the pin supporters. Thus, the frame **14** is held by the slide-contact ring **82**.

In FIG. **7**, the frame **14** is lifted upward along with the slide-contact ring **82** with a predetermined tensile force by an urging force of a lifting spring **88**. Even though a creep elongation generates in the film **38**, the film **38** is always subjected to a predetermined tensile force by the urging force of the lifting spring. The lifting spring **88** may be replaced by a unit such as hydraulic cylinder, air cylinder, disc spring, leaf spring or the like as long as a tensile force is applied to the film **38** automatically even though a creep elongation generates in it. For the purpose of automation, an actuator such as cylinder, motor or the like may be used.

The polishing of the glass substrate G is carried out by conveying the glass substrate G from the stage **16** to the first polishing stage **18** by the conveying device **150**, and by a conveying sequentially the glass substrate G from the first polishing stage **18** to the second polishing stage **20** by the conveying device **152**. When the polishing of the glass substrate G is finished in the second polishing stage **20**, the frame **14** is removed from the carrier **52**, and it is conveyed to the stage **22** by the conveying device **154**. The method for removing the frame **14** from the carrier **52** is described. First, the screw jack **92** as shown in FIG. **5** is operated to reduce the tensile force of the film **38**. Then, the frame **14** is turned by a predetermined angle with respect to the carrier **52** to disengage the head portion **110** from the hook **112**. Thus, the frame **14** can be removed from the carrier **52**.

FIG. **8** shows an example of the conveying device **150** (**152**, **154**). This conveying device **150** has holders **162**, **162** for holding the upper frame **40** and the lower frame **42** of the frame **14**. These holders are arranged at both sides of the conveying route for the frame **14** and they are connected respectively to arms **166** of small robots **164** so that the holders are moved vertically and horizontally by the movement of the arms **166**. A guide block **168** is fixed to a lower portion of each small robot **164**, and this guide block **168** is fitted to each guide rail **170** which is arranged at each side of the conveying route for the frame **14**. Further, the feed screw of a feed screw unit (not shown) is engaged with each of the guide blocks **168** whereby the glass substrate G is held by the conveying device **150** (**152**, **154**) and is conveyed to a predetermined position.

On the other hand, in the stage **22** shown in FIG. **1**, the glass substrate G to which the polishing is finished is removed from the frame **14** conveyed by the conveying device **154**. The removed glass substrate G is conveyed by a conveyer **138** and is sucked to a suction head **144** attached to an arm **142** of a robot **140**. The robot **140** transfers the glass substrate onto the glass substrate discharging conveyer **24** to be discharged outside the polishing device **10**.

The frame **14** from which the glass substrate G is removed is conveyed to the frame washing stage **26** by means of a conveyer **146** to be washed with water. The washed frame **14** is conveyed to the frame drying stage **28** by a conveyer **148**, in which it is heated and dried. Then, the dried frame **14** is conveyed to the stage **16** by the frame returning conveyer **30** to be used again for attaching another glass substrate G.

According to the polishing device **10** for the glass substrate G, constructed as mentioned above, after the completion of the polishing of the glass substrate G in the second polishing stage **20'**, the frame **14** is conveyed from the second polishing stage **20** to the stage **22** by the conveying device **154**, and in the stage **22**, the polished glass substrate G is removed from the frame **14**. Namely, the polishing device **10** of this embodiment is not constituted so that the glass substrate G is attached to the frame **14** to be attached to or detached from the carrier **52**, and after the completion of the polishing, the glass substrate G is removed from the frame **14** in the second polishing stage **20**, but is constituted so that the polished glass substrate G is removed from the frame **14** in the stage **22** located apart from the second polishing stage **20**. Accordingly, it is possible to solve the problem of discharging a special glass substrate G such as a large-sized glass substrate having, for example, a side exceeding 1,000 mm (the problem that it is very difficult to removing the glass substrate in the polishing stage, handling and discharging it, whereby it takes a long time, and therefore, productivity is decreased). Thus, productivity can be improved.

Further, in the polishing device **10**, the frame **14** from which the glass substrate G is removed is washed in the frame washing stage **26**, is dried in the frame drying stage **28**, then, is conveyed to the stage **16**, and is used repeatedly for attaching glass substrates G. Accordingly, it is enough to prepare the minimum necessary number of frames **14**. This contributes resource saving.

Further, according to the polishing device **10**, compressed air is supplied from the air pump **106** to the space between the carrier **52** and the film **38** of the frame **14** so that the glass substrate G is pressed to the polishing pad **58** (**60**) for polishing by the pressure of the compressed air. Accordingly, each portion of the glass substrate G is applied with a uniform pressure whereby the glass substrate G can be polished flat. Further, the polishing is not influenced by the surface configuration of the polishing pad **58** (**60**). Namely, even though the front surface of the polishing pad **58** (**60**) has more or less undulation, there is no danger that the undulation is transferred to the glass substrate G. Accordingly, it is unnecessary to finish precisely the polishing pads **58** (**60**), and therefore, cost for the polishing pads **58** (**60**) can be suppressed.

Further, the film **38** of the frame **14** has a three-layer structure comprising the air-tightness retention layer **44**, the strength retention layer **46** and the smooth layer **48**. Accordingly, the glass substrate G can be held stably on the film **38**, and therefore, the glass substrate G can be polished with precision.

Further, the strength retention layer **46** is made of alamide fibers, a mesh of stainless steel, a mesh of steel, carbon fibers, glass fibers, nylon fibers, a metal sheet, a resin sheet or a material having the same tensile strength as these materials. Accordingly, when the glass substrate G is pressed to the polishing pads **58** (**60**) with a pressing force suitable for the polishing, the strength of the film **38** can be assured.

Here, the tensile strength described herein indicates a tensile strength ruled in JIS L1096 (1999) or the standard pursuant thereto, when the strength retention layer **46** is made of fabric, and indicates a tensile strength used commonly when it is made of a resin sheet or metal sheet (for example, JIS K7161 (1994) in a case of plastics, or a standard pursuant thereto, the same as in the case of metal).

FIG. **9** shows another example of the process for attaching a glass substrate G to a frame **14** with respect to a carrier **52**. This attaching process is carried out in the stage **16**.

As shown in FIG. **9**(*a*), an unpolished glass substrate G is placed on a table **200** provided in the stage **16**, and the frame **14** is supported above by means of jacks **202**, **202**. On the other hand, the carrier **52** is above the frame **14** in a standby state. This state is an initial state of attaching. FIG. **9**(*b*) shows a state that the carrier **52** is moved downward from the initial state of attaching to contact the frame **14**. This state is a state of initiating the attachment of the frame **14** by utilizing screw jacks **92** or the like.

Then, as shown in FIG. **9**(*c*), the head portion **110** of the pin **108** (see FIG. **5**) of the frame **14** is engaged with the hook **112** fixed to the lower portion of the slide-contact ring **82**. Then, the screw jacks **92** are driven to stretch the film **38** of the frame **14** to have a predetermined tensile force. Thus, the frame **14** is attached to the carrier **52**.

FIGS. **9**(*d*) and **9**(*e*) show the process for attaching the glass substrate G to the film **38** of the frame **14**. First, as shown in FIG. **9**(*d*), air is supplied to the air chamber **54** via the air supply channel **102** to inflate the film **38** so that the film **38** is attached to the entire surface of the glass substrate G. When the attaching is completed, air in the air chamber **54** is released through the air supply channel **102** to shrink the film **38** as shown in FIG. **9**(*e*). Thus, both the operation of attaching the frame **14** to the carrier **52** and the operation of attaching the glass substrate G to the frame **14** can be carried out in a single stage **16**.

FIG. **10** shows the process for removing a polished glass substrate G from a frame **14**, the process being carried out in the stage **22**.

As shown in FIG. **10**(*a*), when the carrier **52** is located above a table **204** located in the stage **22**, air is supplied to an air chamber **54** via an air supply channel-**102** to inflate the film **38**. This state is an initial state for separating the glass substrate G. By causing this state, the glass substrate G can easily be separated from the film **38** due to a relative change of position between the glass substrate G and the film **38** and the elastic force of glass substrate G by which the glass substrate tends to be flat. Namely, the process for separating the substrate, which conventionally imposed a burden to the equipment for separating, can be easy by inflating the film **38**.

In this embodiment, an attempt is made to shorten the tact. Namely, as shown in FIG. **10**(*b*), water and air, or only water, or only air (fluid) is injected through a plurality of air jet nozzles **206**, **206** (which may be water jet nozzles, as supply means for supplying fluid for separation) which are arranged at opposed positions with respect to edge portions of the glass substrate G, to the boundary between the edge portions of the glass substrate G and the film **38**. Thus, the glass substrate G is separated from the film **38** by the energy of the injection as shown in FIG. **10**(*c*) although the nozzles **206** are omitted in FIG. **10**(*c*).

FIG. **10**(*d*) shows a state that the glass substrate G is separated completely from the film **38** and is placed on the table **204**. Then, the glass substrate G is conveyed by the conveyer **138** shown in FIG. **1**, is transferred on the glass substrate discharging conveyer **24** by means of a robot **140**, and is discharged outside the polishing device **10**.

On the other hand, when the glass substrate G is separated completely from the film **38** as shown in FIG. **10**(*d*), the frame **14** is removed from the carrier **52** by means of a removing device to place it on jacks **208**, **208** as shown in FIG. **10**(*e*). This frame **14** is conveyed to the frame washing stage **26** by the conveyer **146** shown in FIG. **1**.

FIG. **11** is a front view of a polishing device **300** according to a second embodiment wherein the same reference numerals designate the same or similar parts as the polishing device **10** according to the first embodiment shown in FIGS. **1** to **10**.

The characteristic feature of the polishing device **300** shown in FIG. **11** resides in that two polishing heads **50**A, **50**B are moved horizontally along a rail **302** to transfer the frame **14** (see FIG. **3**) to not only from the first polishing stage **18** to the second polishing stage **20** but also from a frame installing stage **304** to the first polishing stage **18** and from the second polishing stage **20** to a frame removing stage **306**. With this, the tact for manufacture can be improved.

The polishing device **300** comprises mainly a plate attaching shuttle **310** with a table **308** on which an unpolished glass substrate G is placed, a glass substrate attaching stage **16** having a press roller **312**, a frame installing stage **304** for installing the frame **14** on the carrier **52**, a first polishing stage **18**, a second polishing stage **20** and a frame removing stage **306** for removing the frame **14** from the carrier **52**. The frame removing stage **306** serves as a glass substrate removing stage **22** in which the polished glass substrate G is removed from the frame **14**. Reference numeral **314** designates a plate separating shuttle for discharging the polished glass substrate G from the glass substrate removing stage **22**. The polishing device **300** is also provided with a frame washing stage, a frame drying stage and a frame returning conveyer in the same manner as the polishing device **10** although these elements are omitted in FIG. **11**.

In the following, the sequence of polishing the glass substrate G by the polishing device **300** will be described.

On the table **308** of the plate attaching shuttle **310** in the glass substrate attaching stage **16** in a standby state, a glass substrate G conveyed by a robot (not shown) is placed so that the surface to be polished faces downward. The table **308** is mounted on the plate attaching shuttle **310** by interposing an elevating device **316**. When the glass substrate G is placed on the table, the elevating device is elongated so that the table projects slightly from an upper edge portion **311** of the shuttle on which the frame **14** is placed. The upper edge portion **311** has the shape corresponding to the shape of the frame **14**. Namely, when the frame **14** is rectangular, it has also a rectangular shape.

Then, the plate attaching shuttle **310** is moved from the glass substrate attaching stage **16** to the frame installing stage **304** and the table **308** is moved lower than the upper edge portion **311** of the plate attaching shuttle **310** so as not to interfere the positioning of the frame **14** as shown in FIG. **12**. Then, in the frame installing stage **304**, the frame **14** conveyed by the frame returning conveyer (not shown) is placed on the upper edge portion **311** of the plate attaching shuttle **310** so that the film **38** of the frame **14** is positioned above the glass substrate G. In this case, it is preferable to provide a plurality of guide rollers on the upper edge portion **311** in order to make the positioning of the frame **14** easy.

When the plate attaching shuttle **310** receives the frame **14**, the shuttle **310** is moved to the glass substrate attaching stage **16** as shown in FIG. **13**. In association with this moving action, the press roller **312** positioned above the glass substrate attaching stage **16** in a standby state is descended by the extension of a cylinder unit **313** to press the film **38** to the glass substrate G. This press roller **312** has a longer width than the width of the glass substrate G (the length in a direction perpendicular to the moving direction). The operational timing of the attaching is controlled by a controller (not shown) so that the film **38** is pressed to the glass substrate G on the moving plate attaching shuttle **310** just before the front edge portion of the moved glass substrate G passes just below the press roller **312**. Further, the press roller **312** continues the pressing operation until the rear edge portion of the moved glass substrate G on the plate attaching shuttle **310** passes away as shown in FIG. **14**. The operational timing of the press roller is controlled by the controller so that it is retracted upward from the pressing position to the film **38** as shown in FIG. **15**.

With the pressing operation of the press roller **312** and the movement of the plate attaching shuttle **310**, the film **38** is attached to the glass substrate G in the glass substrate attaching stage **16** without causing air bubbles between the film **38** and the glass substrate G.

The attaching of the glass substrate G with use of the press roller **312** is effective for a polishing device for polishing, in particular, a large-sized glass substrate. In the case of a small-sized glass substrate, the glass substrate can be attached to the film **38** without causing air bubbles between the glass substrate and the film **38** by pressing simply the film **38** to the glass substrate. The presence of air bubbles reduces the attaching strength. Accordingly, the quantity of air bubbles should be reduced as possible in order to assure the attaching. On the other hand, in the case of a glass substrate having a large surface area, if the glass substrate is simply pressed to the film **38**, the quantity of air bubbles increases because both the glass substrate and the film have a high flatness. Accordingly, the film **38** is pressed to the glass substrate G by the aid of the press roller **312** to attach them while air bubbles existing between the film **38** and the glass substrate G are discharged outside forcibly. Thus, the glass substrate G can certainly and strongly be attached to the film **38** even in the case of glass substrate G of large surface area. In this embodiment, the attaching is carried out by moving the frame **14** and the glass substrate G with respect to the press roller **312**. However, the attaching may be carried out by moving the press roller **312** with respect to the frame **14** and the glass substrate G. Further, the press roller is preferably made of a flexible material without causing the damage of the film **38**, such as plastic, rubber, urethane or the like. It goes without saying that the pressing force of the press roller **312** is determined so as not to damage the glass substrate G.

The frame **14** with the film **38** attached with the glass substrate G is conveyed by the plate attaching shuttle **310** to the position just below the frame installing stage **304** as shown in FIG. **16**. Then, the elevating device **316** of the plate attaching shuttle **310** is driven to raise the frame **14** toward the carrier **52** of the polishing head **50**A so that the frame **14** is installed on the carrier **52**. Then, the screw jacks **92** are operated to lift the frame **14** so that the film **38** has a predetermined tensile force. Thus, the installation of the frame **14** on the carrier **52** of the polishing head **50**A is completed.

Here, when the film **38** is stretched by the operations of the screw jacks **92**, a local portion of the film **38** may deviate with respect to the glass substrate G to reduce the attaching strength. In order to avoid such disadvantage, the table **308** is raised slightly by the elevating device **316** so that the glass substrate G is pressed to the film **38** by the table **308** as shown in FIG. **18**. Thus, the secondly attaching of the glass substrate G to the film **38** prevents the frame **14** from dropping from the polishing head **50**A when the frame **14** is conveyed by the polishing head **50**A.

The film **38** may be attached to the glass substrate G in the glass substrate attaching stage **16** after the frame **14** is installed on the polishing head **50**A in the frame installing stage **304**.

When the installation of the frame **14** is finished in the frame installation stage **304**, the plate attaching shuttle **310** is returned to the glass substrate attaching stage **16** as shown in FIG. **19**, and the shuttle is remained on standby at this position until another glass substrate G is placed on the table **308**.

On the other hand, the polishing head **50**A on which the frame **14** is installed is moved along the rail **302** to the first polishing stage **18**, and the first glass substrate G attached to the frame **14** is pressed to the polishing pad **58** of the first polishing stage **18** and is subjected to rough polishing, as shown in FIG. **20**. During the rough polishing, the second glass substrate G is placed on the table **308** of the plate attaching shuttle **310** and the glass substrate is conveyed by the plate attaching shuttle **310** to the frame installation stage **304** as shown in FIG. **20**. Then, a frame **14** is placed on the plate attaching shuttle **310**.

When the second frame **14** is placed on the plate attaching shuttle **310**, the film **38** of the first frame **14** is conveyed from the rough polishing process in the first polishing stage **18** as shown in FIGS. **21** to **25** to the second polishing stage **20**. In the meantime, the film is pressed to a second glass substrate G by means of the press roller **312** to perform the attaching. Explanation of the attaching process by the press roller **312** is omitted because it is the same as that shown in FIGS. **13** to **15**. The second glass substrate G in a standby state in that it is attached completely to the film **38**. When the rough polishing is finished in the first polishing stage **18**, the polishing head **50**A is moved along the rail **302** to the second polishing stage **20**.

After the movement to the second polishing stage **20**, the screw jacks **92** of the polishing head **50**A are relaxed in the state that the glass substrate G is placed on the polishing pad **60**, and the frame **14** is removed from the polishing head **50**A. Then, the polishing head **50**A is raised in the state that the frame **14** is placed on the polishing pad **60** as shown in FIG. **26**. During this time, the second glass substrate G is attached to the frame **14** and is in a standby state in the frame installing stage **304**.

Then, the polishing head **50**A is moved to the frame installing stage **304**, and the polishing head **50**B which is in a standby state in the substrate removing stage **22** (frame removing stage **306**) is moved to the second polishing stage **20** in which the frame **14** on the polishing pad **60** is installed on the polishing head **50**B. In this case, the position of the film **38** with respect to the glass substrate G may deviate to cause a reduction of the attaching force since tensile force is again imparted to the relaxed film **38** by the screw jacks **92**. To avoid this, compressed air (see FIG. **5**) is supplied to the space between the carrier **50** of the polishing head **50**B and the film **38** after the film is stretched by the screw jacks **92**, so that the film **38** can be pressed to the glass substrate G as shown in FIG. **28**. Accordingly, the secondary attaching of the film to the glass substrate G is performed whereby the dropping of the glass substrate from the polishing head **50**B can be prevented. Then, the glass substrate G is subjected to fine polishing by the polishing pad **60** of the second polishing stage **20** in the state that the glass substrate is attached to the side of the polishing head **50**B. On the other hand, another frame **14** is attached to the polishing head **50**A.

When the next frame **14** is attached to the polishing head **50**A, the polishing head **50**A is moved to the first polishing stage **18** and the second glass substrate G is subjected to rough polishing in the stage **18** as shown in FIG. **29**. During the rough polishing, the plate separating shuttle **314** is moved to the substrate removing stage **22** (frame removing stage **306**) to be in a standby state. Then, the polishing head **50**B is moved to the substrate removing stage **22** (frame removing stage **306**) as shown in FIG. **30**. The plate separating shuttle **314** has a table **320** for the glass substrate G and the table **320** is provided on the shuttle main body **324** by interposing an elevating device **322**.

When the plate separating shuttle **314** is moved to the substrate removing stage **22** (frame removing stage **306**), the screw jacks **92** of the polishing head **50**B are relaxed so that the frame **14** is removed from the polishing head **50**B and is placed on the upper edge portion **328** of a conveying table **326** as shown in FIG. **31**.

Then, air (water: fluid) is injected from a plurality of air jet nozzles (which may be water jet nozzles: a supply means for supplying fluid for separation) provided on the conveying table **326** to the boundary between edge portions of the glass substrate G and the film **38** to separate the glass substrate G by utilizing the energy of the injected fluid as shown in FIG. **32**. The separated glass substrate G is placed on the table **320** of the plate separating shuttle **314** as shown in FIG. **33**. During the separating operation of the glass substrate G, the second glass substrate G is conveyed to the second polishing stage **20** by means of the polishing head **50**A. The frame **14** is removed from the polishing head **50**A, and the polishing head **50**A is moved to the frame installing stage **304**. Then, the polishing head **50**B is moved to the second polishing stage **20**. Then, the glass substrate G is subjected to fine polishing by the polishing pad **60** of the second polishing stage **20** in the state that it is attached to the side of the polishing head **50**B.

Instead of separating forcibly the glass substrate G from the film **38** by utilizing the fluid in the substrate removing stage **22** (frame removing stage **306**), the glass substrate G can be separated from the film **38** by its own weight, without using fluid. Then, the separated glass substrate G is placed on the carriage **320** of the plate separating shuttle **314** and is conveyed from the substrate removing stage **22** (frame removing stage **306**) to a product storage space as shown in FIG. **34**. By repeating the above-mentioned series of operations, glass substrates G can continuously be polished with good efficiency.

Further, the frame **14** may be removed from the polishing head **50**B after the glass substrate G is separated from the film **38** in the substrate removing stage **22** (frame removing stage **306**).

FIGS. **35** and **36** are diagrams showing the structure for determining the position of the frame **14** with respect to the slide-contact ring **82** of the carrier **52**. In FIG. **35**, a plurality of pins **340**, **340** . . . (only two pins are shown in FIG. **35**) are provided on the frame **14** and openings **342**, **342** . . . to be fitted with these pins **340**, **340** . . . are formed in the slide-contact ring **82**. By fitting the pins **340**, **340** . . . to the openings **342**, **342** . . . , the position of the frame **14** with respect to the slide-contact ring **82** is determined.

A predetermined number of pins **340** among the plurality of pins **340**, **340** . . . are attached to the frame **14** so as to be swung as shown in FIG. **35**, and the remaining pins **340** are fixed firmly to the frame **14** in order to determine the position of the frame with respect to the carrier.

The attachment of the pins **340** to the frame **14** so as to be swung is effective for the polishing device for polishing, in particular, a glass substrate G having a large surface area. In the case of connecting the frame **14** to the slide-contact ring **82** (i.e., the carrier **52**) for determining mutual positions by fitting the plurality of pins **340**, **340** . . . provided on the frame **14** to the plurality of openings **342**, **342** . . . formed in the slide-contact ring **82**, if the frame is a small-sized frame, the pins **340** can be attached with high precision. Accordingly, all the pins **340**, **340** . . . can be fitted to the openings without any difficulty even though the all pins **340**, **340** . . . are attached fixedly to the frame.

On the other hand, in the case of using a large-sized frame **14** for attaching a glass substrate G having a large surface area, it is difficult to attach the pins **340** with higher precision. Accordingly, if all the pins **340**, **340** . . . are attached fixedly to the frame **14**, it is difficult to fit all the pins **340**, **340** . . . into the openings **342**, **342** . . . . On the other hand, if all the pins **340**, **340** . . . are attached to the frame **14** so as to be swung, the fitting of the pins **340**, **340** . . . can be easy because error in the attachment can be absorbed by the swinging movement of the pins. In this case, however, if the all the pins **340**, **340** . . . are provided so as to be swung, the position of the frame **14** becomes unstable because there is a possibility of shift of the frame **14** with respect to the carrier **52**. Further, there is a possibility that the pins **340** can not withstand the shearing force applied by the polishing pad **58** (**60**) at the time of polishing.

Accordingly, in the embodiment as shown in FIG. **35**, a predetermined number of pins **340** among the plurality of pins **340**, **340** . . . are attached to the frame **14** so as to be swung so that error in the attachment can be absorbed by these swing pins **340**. The remaining pins (e.g., two pins) **340**, **340** are attached fixedly to the frame **14** so that these pins **340**, **340** . . . can withstand the shearing force applied from the polishing pad **58** (**60**). Accordingly, the large-sized frame **14** can be positioned precisely to the carrier **52** and a steady connection can be assured.

Further, each pin **340** has a tapered portion at its tip portion **344** so as to make the fitting of the pin **340** to the opening **342** easy, and further, a thin portion **346** is formed at the boundary between the tip portion **344** and a cylindrical main body portion **341**. The thin portion **346** projects from the opening **342** when the pin **340** is fitted to the opening **342**. Further, the thin portion is fitted to a circular-arc-like fitting portion **352** of a hook **350** shown in FIG. **36**. This hook **350** is attached to the carrier **52** so as to be rotatable around a fixed support O. When the hook is rotated in a counterclockwise direction from the state shown in FIG. **36** (A), the hook is fitted to the thin portion **346** of the pin **340**. Thus, the frame **14** can be held on the carrier **52** by engaging the pin **340** with the hook **350**.

FIG. **37** is a diagram showing another embodiment of the glass substrate attaching stage **16** shown in FIG. **11**, in which a film pressing balloon **360** is provided in addition to the press roller **312**.

The film pressing balloon **360** is made of rubber and is formed to have a circular shape. The balloon is disposed to close the opening at a lower portion of a head **362**. The balloon **360** is inflated by supplying compressed air from an air supply source (not shown) into the space between the head **362** and the film pressing balloon.

The head **362** is attached to a support frame **364** for supporting the press roller **312** via a cylinder unit **366** so as to be ascended and descended, namely, the head is advanced and retracted with respect to the frame **14** disposed above the glass substrate G.

An example of the attaching method using the film pressing balloon **360** will be described. First, before the attaching by using the press roller **312**, the film pressing balloon **360** inflated is pressed to the central portion of the film **38** to contact closely the central portion of the film **38** to the glass substrate G. Then, the film pressing balloon **360** is retracted upward from the frame **14**, and then, the attaching by the press roller **312** is initiated. Thus, it is possible to carry out the stable attaching without air bubbles between the film **38** and the glass substrate G.

INDUSTRIAL APPLICABILITY

As described above, in the method and device for polishing a substrate according to the present invention, a substrate is attached to a frame which can be attached to or detached from a carrier, and after the completion of the polishing in a polishing stage, the polished substrate is removed from the frame in a substrate removing stage which is remote from the polishing stage. Accordingly, it is possible to solve the problems of the reduction of productivity due to the stopping of the polishing machine when a large-sized substrate is removed and discharged. Therefore, productivity can be improved remarkably. Namely, when a substrate is polished, another substrate can be attached to a frame or another substrate having been subjected to polishing can be removed. Accordingly, stable working can be assured and a large-sized substrate can safely be polished with stable quality.

Further, in the present invention, the frame from which a substrate is removed is washed in a washing stage and then, the frame can be used for attaching another substrate. Accordingly, it is enough to prepare a necessary minimum number of frames, and therefore, it serves resource saving.

In addition, in the present invention, pressurized fluid is supplied from a supply means for supplying pressurized fluid for polishing between the carrier and the film of a frame so that the substrate is pressed for polishing to a polishing surface-plate by the pressure of the pressurized fluid.

Accordingly, each portion of the substrate is applied with uniform pressure and therefore, the substrate can be polished flat.

Further, the film of the present invention has a three-layered structure comprising an air-tightness retention layer having its outer peripheral portion in contact hermetically with the carrier to thereby maintain air-tightness with respect to the carrier, a strength retention layer holding the air-tightness retention layer and having a predetermined tensile strength durable to a tensile force for stretching the film and a smooth layer to which the substrate is attached. Accordingly, the substrate can stably be held by the film and the substrate can be polished with high precision.

In addition, the strength retention layer of the film is made of alamide fibers, a mesh of stainless steel, a mesh of steel, carbon fibers, glass fibers, nylon fibers or a material having the same tensile strength as these materials. Accordingly, it is possible to guarantee the strength of the film when the substrate is pressed to the polishing surface-plate with a pressing force suitable for polishing.

Further, in the present invention, the substrate can be separated from the frame by a separating function which is obtained by supplying fluid from a supply means for supplying fluid for separation to the boundary between the film of the frame and edge portions of the substrate. Accordingly, the substrate can be separated from the frame in a shorter time to thereby improve productivity.

Further, in the present invention, the substrate is placed on a table in a substrate attaching stage, and then, the film of a frame is put on the substrate placed on the table, and then, a press roller is pressed to the film on the substrate while the table and the press roller are moved relatively along the surface of the film by a moving means whereby the substrate is attached to the film by the press roller. Accordingly, the substrate can certainly and firmly attached to the film even when the substrate has a large surface area.

Further, in the present invention, the frame and the carrier are attached to or detached from each other by means of a plurality of pins wherein a predetermined number of pins among the plurality of pins are attached to the frame so as to be swung, and the remaining pins are attached fixedly to the frame so as to serve the determination of the position with respect to the carrier. Accordingly, the position of a large-sized frame to the carrier can be correct and they can stably be connected.

The entire disclosure of Japanese Patent Application No. 2002-223001 filed on Jul. 31, 2002 including specification, claims, drawings and summary is incorporated herein by reference in its entirety.

What is claimed is:

1. A method for polishing a substrate comprising:

attaching a substrate to a film on a frame;

bringing the frame and a polishing surface-plate closer relative to each other and polishing a surface of the substrate attached to the film by pressing the surface of the substrate to the polishing surface-plate; and

removing the substrate from the film on the frame after completing the polishing of the surface of the substrate,

wherein the substrate is removed from the frame by supplying fluid to the boundary between the film on the frame and an edge portion of the substrate.

2. A device for polishing a substrate comprising:

a substrate attaching stage configured to attach a substrate to a frame by attachment to a film on the frame;

a polishing stage configured to polish the substrate by bringing the frame and a polishing surface-plate closer relative to each other and pressing a surface to be polished of the substrate attached to the film attached to the frame to the polishing surface-plate; and

a substrate removing stage configured to remove the polished substrate from the film on the frame,

wherein the substrate removing stage is provided with a supply means for supplying fluid to the boundary between the film on the frame and an edge portion of the substrate to remove the substrate from the frame.

3. A method for polishing a substrate comprising:

attaching a substrate to a film on a frame, wherein the step of attaching the substrate to the film on the frame comprises,

placing the substrate on a table,

placing the film attached to the frame on the substrate placed on the table, and

pressing a press roller to the film placed on the substrate while the table and the press roller are moved relatively along the surface of the film, whereby the substrate is attached to the film by the press roller;

bringing the frame with the attached film having the attached substrate and a polishing surface-plate closer relative to each other and polishing a surface of the substrate by pressing the surface of the substrate to the polishing surface-plate; and

removing the substrate from the film attached to the frame after completing the polishing of the surface of the substrate.

4. A device for polishing a substrate comprising:

a substrate attaching stage configured to attach a substrate to a frame by attachment to a film on the frame, wherein the substrate attaching stage comprises,

a table on which the substrate is placed and covered by the film attached to the frame,

a press roller, and

a moving means for moving the table carrying the substrate covered by the film attached to the frame and the press roller relative to each other so that the press roller is pressed to the film covering the substrate while the table and the press roller are moved relative to each other along the surface of the film, whereby the film attached to the frame is attached to the substrate by the press roller;

a polishing stage configured to polish the substrate by bringing the frame and a polishing surface-plate closer relative to each other and pressing a surface to be polished of the substrate attached to the film attached to the frame to the polishing surface-plate; and

a substrate removing stage configured to remove the polished substrate from the film on the frame.

5. A device for polishing a substrate comprising:

a substrate attaching stage configured to attach a substrate to a frame by attachment to a film on the frame;

a frame installing stage configured to detachably connect the frame to a carrier via a plurality of pins, wherein a predetermined number of pins among the plurality of pins are fitted to be swung to the frame, and the remaining pins are fixed thereto so as to be used for determining the position to the carrier;

a polishing stage configured to polish the substrate by bringing the frame connected to the carrier and a polishing surface-plate closer relative to each other and pressing a surface to be polished of the substrate attached to the film attached to the frame connected to the carrier to the polishing surface-plate; and

a substrate removing stage configured to remove the polished substrate from the film on the frame.

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